

Integrated Pest Management for Rice Production in Nigeria



Report on a consultancy for the CARI program by Dr. Otto Mück

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Acronyms

Acronym	Significance
2,4-D	2,4-Dichlorophenoxyacetic acid
ADI	Acceptable Daily Intake
ADP	Agricultural Development Project
AESA	Agro-Ecosystem Analysis
AfRGM	African Rice Gall Midge
AGAN	Agricultural Graduate Association of Nigeria
ARfD	Acute Reference Dose
BMGF	Bill and Melinda Gates Foundation
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Economic Cooperation and Development)
CARI	Competitive African Rice Initiative
DDT	Dichlorodiphenyltrichloroethane
DDVP	Dichlorvos
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FEPA	Federal Environmental Protection Agency of Nigeria
FFS	Farmer Field Schools
FMEV	Federal Ministry of Environment of Nigeria
FMLP	Federal Ministry of Labour and Productivity of Nigeria
GHS	Globally Harmonized System of Classification, Labelling and Packaging of Chemicals of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Agency for International Cooperation)
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, now GIZ
IPM	Integrated Pest Management
IRAC	International Resistance Action Committee
IRRI	International Rice Research Institute
LGA	Local Government Area
MD	Man Days
MRL	Maximum Residue Limit
MSDS	Material Safety Data Sheet
N	Nitrogen
NACGRAB	National Centre for Genetic Resources and Biotechnology of Nigeria
NAFDAC	National Agency for Food and Drug Administration and Control of Nigeria

N.A.S.C	National Agricultural Seeds Council of Nigeria
NCRI	National Cereals Research Institute of Nigeria
NERICA	New Rice for Africa
NESREA	National Environmental Standards and Regulation Enforcement Agency
NFDP	National Fadama Development Project
PAN	Pesticide Action Network
PIC	Prior Informed Consent
PICS	Purdue Improved Crop Storage
PLAR	Participatory Learning and Action-Research
POP	Persistent Organic Pollutant
PPP	Public Private Partnership
R&D	Research and Development
RYMV	Rice Yellow Mottle Virus
TG-PPP	Thai-German Plant Protection Programme
TOR	Terms of Reference
UBA	Umweltbundesamt (German Federal Environment Agency)
ULV	Ultra-low volume
WHO	World Health Organisation of the United Nations

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Executive Summary

This study on integrated pest management (IPM) on rice in Nigeria was carried out for the CARI (Competitive African Rice Initiative) program to define and systematically introduce Integrated Pest Management (IPM) practices in order to avoid the risk of indiscriminate increase in use of agro-chemicals. The consultancy described in this study aimed at establishing a framework for the application of Integrated Pest Management practices by smallholder rice farmers by defining best IPM practices (including pest and weed control) relevant for small-holder rice producers in the target production systems, economic thresholds for the application of pesticides, and training guidelines for small-holder rice producers.

The study provides an overview of biotic constraints for rice production in tropical Africa with special reference to Kogi and Niger States as documented in the literature and observed in Nigeria by the consultant. Textbooks and field manuals describe weeds as main sources of losses alongside with diseases, in particular rice blast (*Magnaporthe oryzae*), rice yellow mottle virus (RYMV), and bacterial blight (*Xanthomonas oryzae*). Major pests commonly quoted are the African rice gall midge (AfRGM, *Orseolia oryzivora*), different stem borer species (Lepidoptera), stalk-eyed shoot flies (*Diopsis* spp.), termites, rodents and birds such as weaver birds and geese.

Information collected during the consultancy including field observations confirmed the importance of weeds including wild rice (*Oryza longistaminata*), sedges and, in upland rice, *Striga hermonthica* while diseases were found to be of minor importance in the field. On all occasions during the mission (field visits and meetings with experts), the red-billed weaver (*Quelea quelea*) was reported to be the most important pest species, followed by field rodents. Other pests of some importance reported and observed were termites, stem borers (in particular the white stem borer - *Maliarpha separatella*) and stalk-eyed shoot flies while others were mentioned as occasional pests only. The main post-harvest loss agents encountered were commensal rodents.

Pest management recommendations found in field guides and other sources have been reviewed and a critical review is provided in this study. Most of the recommendations available are outdated in terms of pesticides that have been proposed for control because of their undesirable characteristics in terms of consumers' safety and environmental hazards (e.g. persistence, bioaccumulation, neurotoxicity, endocrine disruptive action, toxicity for aquatic organisms, etc.)

Pest management commonly practiced by farmers in Nigeria include agricultural practices such as destruction of crop residues, pre- and post-emergence herbicide application, scaring of birds, and occasional use of fishing nets to protect the rice panicles against bird damage. Hand weeding is not common apart from some instances in nurseries. Insecticide use in the field was reported occasionally and fungicide use hardly ever. Seed treatment is common and protection of stored grain with aluminium phosphide tablets, too. These tablets that release a very toxic gas, however, are used under extremely hazardous conditions. Their use by farmers and other untrained applicators should be entirely banned. The range of pesticides registered in Nigeria and available in the market to control weeds, pests and diseases in rice is limited and problematic in terms of active ingredients involved. Commercial products containing substances such as 2,4-D amine, benomyl, carbofuran, dichlorvos (DDVP), paraquat, and mixtures of cypermethrin, λ -cyhalothrin and benomyl should not be applied any longer because of their health and environmental hazards.

Rice loss estimates due to biotic constraints published in the literature are partially very high but do not always correspond to the situation in Nigeria. It can be supposed that losses due to weeds would be substantial without control. As herbicide application is kind of a standard there was no possibility to confirm this assumption during the consultancy. Apart from high but varying losses caused by quelea birds other losses were reported to be rather insignificant in most cases (e.g. stem borer losses of generally below 5 %).

Threshold levels have been provided for weeds, diseases and pests in other regions, but not for the specific case of Nigeria. There is some information on the profitability of IPM from Ibaji LGA in Kogi State (benefit cost ratio: 1.95). Economic data available in the CARI program suggest that herbicide treatment as practiced so far (but with recommended herbicides) is profitable. Some preliminary proposals for thresholds related to pests and diseases have been provided in this study but they require further fine tuning. As far as quelea birds are concerned a threshold cannot be fixed due to the nature of the damage caused by these migratory pests that appear all of the sudden in enormous numbers.

Main risks of indiscriminate intensification of pesticide use include intoxication of pesticide applicators (not acute poisoning in the first place but rather long-term effects such as the consequences of neurotoxicity, endocrine disruption and bioaccumulation that may result in damage of vital organs in the long term, for example). In Nigeria, awareness of risks seems to be quite widespread, but at the same time use of appropriate protective equipment is not common. Hazards for consumers may occur in the first place because of lack of a functioning supervision including monitoring of residues. In rice production, environmental hazards are to be expected in particular if active ingredients with high toxicity for aquatic organisms continue to be used (e.g. 2,4-D amine, benomyl, carbofuran, cypermethrin, dichlorvos (DDVP), λ -cyhalothrin, and paraquat). Under the special circumstances of handling and storage of pesticides in Nigeria hazards include decomposition of active ingredients at high temperatures as for example during exposure to the sun in the market.

Regulations on pesticide trade, sale, use and disposal in Nigeria are absolutely insufficient. Apart from registration by the competent authority NASDAC (National Agency for Food and Drug Administration and Control) there is not much regulation at all. The same applies to the policy level. A couple of obsolete products are banned (e.g. PIC and POP chemicals), however, or strictly limited in application.

The pesticide market is dominated by generics mainly from China or India, whose quality is not controlled. Products from renowned international companies are considerably more expensive than the majority of products (about 50 %). Some importers care for safe application but the extent to which they do it varies. Syngenta Nigeria has started a wider campaign of responsible use. Almost all pesticides found in the market carry a NASDAC registration number but many of the active ingredients still in use do not fulfill the requirements of state of the art substances but rather represent older generation chemical groups.

An IPM strategy has been proposed for CARI rice farmers based on available literature sources and extension material as well as on observations made in the field and information obtained from local specialists. This strategy contains the key elements listed below:

- Choice of suitable planting sites with fertile soil
- Proper preparation of the field
- Planting tolerant rice varieties and using healthy seeds
- Planting rice in rows at the right distance to facilitate mechanical weeding instead of broadcasting
- Good timing of rice planting
- Proper timing of weeding
- Good soil management and right fertilization
- Good water/irrigation management
- Regular monitoring of the rice fields
- Proper sanitation

- Responsible pesticide choice and application at the right time
- Protection of natural enemies of weeds and pests
- Efficient protection of the rice crop against quelea birds and rodents (e.g. using nets)
- Good harvesting methods
- Use of appropriate and clean storage facilities including PICS triple bags
- Crop rotation
- Seek advice from extension agents
- Refrain from dubious practices (e.g. seed dressing done by farmers, aluminium phosphide application)

Supporting action to introduce recommended IPM practices improve pesticide use conditions include:

- Making innovative pest control equipment available in all rice growing areas of the CARI program (including rodent and bird nets, triple bags and any other suitable equipment)
- Training professional pest control operators (including in proper use of fumigants under safe conditions)
- Setting up pesticide stewardship programs involving training and promotional sales actions, e.g. pesticide + safety equipment package or sprayer + safety equipment package
- Providing improved safety equipment (e.g. face shields instead of dust masks)
- Selling pesticides, sprayers, protective equipment and other agricultural inputs in the same place to facilitate adoption of good IPM and safety practices
- Support drawing up of pesticide policy taking into account environmental and human health criteria and drafting of a pesticide act, if possible.

In order to disseminate the IPM message to the rice farmers, picture blocks as developed in other projects (e.g. in Benin) are suitable alongside with field demonstrations. Following these recommendations will prove to be cost-effective because they are an essential part of measures to boost crop yields which will raise farmers' incomes substantially.

1. Background and baseline

1.1 Brief description of the CARI program

CARI (Competitive African Rice Initiative) is a program commissioned by Bill and Melinda Gates Foundation (BMGF) and Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in cooperation with Technoserve, Kilimo Trust, and John A. Kufuor Foundation. Its goal is to significantly improve the livelihoods of rice farmers in four African countries (Burkina Faso, Ghana, Nigeria, and Tanzania) by increasing the competitiveness of domestic rice supply to meet increasing regional demand. The outreach target is 120.000 African rice producers, 30 % of which should be women. The aim of the program is to substantially increase incomes for the target smallholders across the four countries by the end of 2017.

According to the planning documents of the program the specific objectives and benefits will be:

- Increase the productivity and quality of paddy rice based on the development of sustainable and competitive rice production systems;
- Increase the sourcing capacity through structured producer-processors-linkages as well as improved storage capacity and processing efficiency;
- Improved access to finance and financial innovation for all value chain actors;
- Shaping and strengthening the enabling environment at national and regional levels, including policy framework and market linkages.

CARI is a partnership based development program. Cooperation with public and private sector partners and the formation of Public Private Partnerships (PPP) plays a pivotal role to achieve these objectives.

In Nigeria, the program is active in two federal states: Kogi and Niger. In both states there is rainfed lowland rice production (with some irrigated rice production in Niger, too) plus upland rice in Kogi.

The Federal Government of Nigeria pursues a policy of poverty alleviation in rural areas (about 70 % of the population are engaged in agricultural production). A number of initiatives have been undertaken by the Government including the World Bank funded National Fadama Development Project (NFDP) destined to increase agricultural production including rice. From this project valuable insights related to the economics of pesticide use could be obtained (Shaibu, 2011) that have been summarized in section 4.2.

1.2 Consultant's tasks

CARI aims to define and systematically introduce Integrated Pest Management (IPM) practices in order to avoid the risk of indiscriminate increase in use of agro-chemicals. With the consultancy described in this study, CARI will establish a framework for the application of Integrated Pest Management practices by smallholder rice farmers by defining:

1. IPM practices (including pest and weed control) relevant for small-holder rice producers in the target production systems;

2. Economic thresholds for the application of pesticides according to current economic framework conditions (prices for inputs and paddy) that will enable the farmer to make informed decisions for the appropriate use of agro-chemicals;
3. Training guidelines for small-holder rice producers.

The country focus of the consultancy was Nigeria (mainly Kogi and Niger States). The aim of this study is to elaborate country-specific recommendations. The results of the consultancy will be adapted by CARI to the other target countries. The consultant's tasks are described in detail in the TOR in Annex 1. The course of the mission is described in Annex 2. Annex 3 contains the outcome of the two Stakeholder Forums on IPM held in Abuja at the beginning and at the end of the mission. Photos taken during the field visits to Niger and Kogi States are included in Annex 4.

2. Rice production constraints due to weeds, diseases and pests

Biotic constraints for rice production in tropical Africa have been well documented in the literature. Reference books on tropical agriculture such as Fröhlich (1974), Onwueme & Sinha (1991), and Purseglove (1985) indicate weeds, diseases and insect pests as major production constraints alongside with abiotic factors such as nutrient deficiencies, salinity and toxicities related to elements such as iron and aluminum. The book by Fröhlich is written in German language and contains a key to major rice pests and diseases based on signs of damage as well as some information on losses (see also chapter 4). Oerke & al. (1994) provide some details on rice crop losses in Africa with breakdowns for regions and countries (cf. chapter 3).

According to Heinrichs & Barrion (2004), 40 % of the West African rice production is upland rice. The remaining 60 % of lowland rice are cultivated in four different agro-ecological environments: rainfed lowland (37 %), irrigated (12 %), deepwater (7 %), and mangrove swamp (7 %), respectively. Weed, pest and disease control in African lowland rice have been dealt with by Nwilene & al. (no year). Oikeh & al. (no year) produced a similar booklet for upland rice. More detailed descriptions of biotic African rice production constraints and their management can be found in Somado & al. (2008) and Wopereis & al. (2013). Heinrichs & Barrion (2004) wrote a detailed book on biology, ecology, and identification of rice-feeding insects and natural enemies in West Africa that contains identification keys. The probably most comprehensive publication on Diseases, Pests and Weeds in Tropical Crops has been edited by Kranz & al. (1977). It is organized according to the systematics of pest organisms and contains plenty of information on distribution, host plants, biology, symptoms, damage, and control (however, the information on chemical control has become largely obsolete since then). Indices of diseases and pests by host plants facilitate practical work with this volume.

The situation for lowland rice cultivation in Nigeria has been described in publications by AfricaRice such as Nwilene & al. (no year) and others. According to the authors, lowland rice accounts for 50 % of the total production in Nigeria. Most of the rice is produced by smallholders with less than 1 ha land. Oikeh & al. (no year) provide a brief introduction to upland rice production constraints in Nigeria.

2.1 Overview of weed problems

In their publication on weed management, Rodenburg & Johnson (2013) describe different negative effects of weeds on the rice crop:

- competition for resources such as nutrients, water and light (practically all weeds)
- parasitism (e.g. *Striga* species)
- action as vectors of rice diseases (e.g. wild rice species)
- attraction of rice pests such as insects, rodents or birds
- obstruction of water flow in irrigation or drainage canals
- decrease in product quality if weed seeds mix with rice grains (*Ischaemum rugosum* and *Rottboellia cochinchinensis* which have seeds similar in shape and size to rice grains)

There are some particularly problematic species that can be characterized according to their biology. Perennial rhizotomous or tuber-bearing species can easily survive adverse conditions. Important species of this type include, amongst others, the Cogon grass (*Imperata cylindrica*), wild rice (*Oryza longistaminata*), the grasses *Leersia hexandra*, and *Sacciolepis africana*, and sedges of the genus *Cyperus*. A different survival strategy is used by competitive, fast-growing or prolific-seed-producing annual weeds such as the spurge weed (*Euphorbia heterophylla*), the sedge *Cyperus difformis*, the goatweed *Ageratum conyzoides*, the goosegrass *Eleusine indica*, and many others.

The Handbook on West African Weeds compiled by Akobundu and Agyakwa (1987) is helpful for identifying aquatic weeds (i.e. weeds of lowland rice) and dryland weeds. It contains descriptions of major weed species with coloured photos including some seedlings. Generally, upland rice has considerably more weed problems lowland rice (Onwueme & Sinha, 1991) and control is more difficult to achieve.

According to information from participants of the stakeholder forum on January 30, 2015 (cf. Annex 3), wild rice and sedges are the biggest challenges amongst the weeds in rice cultivation in the program regions of Nigeria. In upland rice, *Striga hermonthica* was also mentioned to be a major problem. The field visits listed in Annex 2 confirmed the importance of weeds (wild rice in the first place) which were generally considered as the biotic constraint number 1 by farmers, extension agents and other professionals in the field. As herbicide application is commonly practiced, an on-site overview of weeds (species and importance) could not be conducted during the mission.

2.2 Overview of major diseases

The major rice diseases in Africa are rice blast (*Magnaporthe oryzae*), rice yellow mottle virus (RYMV), and bacterial blight (*Xanthomonas oryzae*). These diseases have been thoroughly described in the publications by Nwilene & al. (no year), Oikeh & al. (no year), Somado & al. (2008), Wopereis & al. (2013), and Kranz & al. (1977). Their incidence varies between production systems. While rice blast causes most severe damage in upland rice, it also occurs in lowland production. Most damage due to RYMV occurs in the Sahel, but it is also a problem in lowland, forest and savannah regions. Bacterial blight is distributed in forest, savannah and Sahel regions (Séré & al., 2013). Apart from these three diseases, some secondary pathogens are known such as *Bipolaris oryzae* responsible for brown spot, leaf scald (*Gerlachia oryzae*) and sheath blight (*Rhizoctonia solani*). Other diseases have been classified as of minor importance.

Rice blast is probably the most frequent and most destructive rice disease in Africa. It is caused by the fungus *Magnaporthe oryzae* which can infect rice plants through roots as well as above-ground tissues. Symptoms start from grey-white spots on the leaves which eventually enlarge and cover the entire shoot. Finally the plant withers and dies. Severely attacked fields look as if they have been burnt by fire. Nodes and panicles of older plants can also be attacked which results in collapsing and yield loss. According to Séré & al. (2013) surveys made in Burkina Faso indicated that intensifying rice cultivation may lead to increased yield losses due to blast.

The **rice yellow mottle virus (RYMV)** is the main virus disease of rice in Africa. RYMV disease is transmitted when the sap of infected leaves comes into contact with the cells of healthy leaves. It is also transmitted by many insects including chrysomelid beetles and grasshoppers. Infected plants show pale yellow mottling on their leaves, stunted growth, fewer tillers, asynchronous flower formation, poor panicle exertion, spikelet discoloration and sterility (Séré & al., 2013). As it is the case with rice blast, too, intensification of rice cultivation favours the incidence of the disease.

Bacterial blight is caused by *Xanthomonas oryzae*. The source of infestation is infected plant material such as straw and also wild host plants. The bacteria are distributed via wind and water. The germs enter the host plant through natural openings on the leaf or through wounds from where it spreads throughout the plant, resulting in systemic infection. Symptoms include yellow to white stripes along the leaves which by and by extend all over the leaf. When the bacteria have spread throughout the rice plant, wilting occurs (called 'kresek' symptom).

During the stakeholder forum the importance of blast as rice disease number one was confirmed, followed by RYMV and bacterial blight. Several participants stated that a couple of other fungal diseases may also cause damage but not on a regular base. Information provided by farmers and extension agents contrasted to this picture. Practically all of them indicated that diseases do not play an important role in rice production and that control measures apart from good agricultural practice (e.g. destroying harvest residues) are not commonly practiced. Rice fields visited during the mission were generally in a healthy state. Crop residues close to a field could only be observed in one case in Washe (Annex 4, photos 5007, 5008).

2.3 Overview of main field pests in rice

The book written by Heinrichs & Barrion (2004) is probably the most comprehensive one on biology, ecology, and identification of rice-feeding insects and their natural enemies in West Africa. It contains detailed identification keys. Bohlen (1978) compiled a book on Crops Pests in Tanzania and their control that includes a short section on rice. While photos and descriptions of pests and beneficial insects are still very useful, most of the information on pesticides is outdated now. Risbec (1950) gave a detailed account on insect pests in French language that includes a section of rice pests and detailed line drawings. Another book on pests of tropical crops in French language has been written by Appert & Deuse (1982). It contains a key to rice pests based on symptoms of damage as well as pest characteristics. Nwilene & al. (2013) gave an overview of the most important rice pests in Africa from which most of the information on pest species provided below is taken.

The **African rice gall midge (AfRGM, *Orseolia oryzivora*)** is one of the most devastating insect pests of lowland rice in Africa. Nwilene & al. (2006) published a field guide that deals with biology, ecology and control of this pest exclusively. AfRGM larvae cause severe crop damage from seedling to panicle initiation by producing tube-like 'silver shoot' or 'onion leaf' galls (swellings) that prevent panicle production. Adults are small reddish-brown mosquito-like midges with a wing length of about 3 - 4 mm and a nocturnal way of life. Larvae are whitish maggots and up to 5 mm long. Wild rice species are alternative hosts for AfRGM.

Several **stem borer** species cause substantial damage in African rice. They belong to the noctuid (*Sesamia* spp. – pink stem borers) and pyralid moth families (*Chilo* spp. – African striped stem borers, *Maliarpha separatella* – African white borer, African yellow stem borers – *Scirpophaga* spp.). Their larvae (caterpillars) cause significant yield loss during the vegetative and reproductive stages by boring into the rice stems and producing 'deadhearts' and 'whiteheads' which prevent panicle development. The adults are inconspicuous light-coloured moths with a body size of 2 – 3 cm depending on the species which hold their wings folded over the back when at rest.

Stalk-eyed shoot flies (*Diopsis* spp.) produce similar damage as stem borer moth species. The adult flies are pretty small but their eyes sit at the side of the head on top of stalks that span up to 1 cm.

Termites are social insects that are not really specialized on certain crops. Subterranean termites are common pests of upland rice in West Africa where most of them cause serious damage feeding on rice roots during dry periods. Termites cannot survive in flooded fields. *Macrotermes* spp. cut seedlings at the base of the stem. They build mounds that can become quite huge and host up to 2 million individuals. Foraging galleries can be as long as 50 m (Heinrichs & Barrion, 2004).

Participants of the stakeholder forum emphasized that stem borers (in particular the white stem borer - *Maliarpha separatella*) and stalk-eyed shoot flies were the most common insect pests while AfRGM was said to be of minor importance. Reference was made to migratory pests, too, such as locusts and armyworms, but participants admitted that their occurrence is rather erratic and that effective control measures are not in place.

Rodent damage in the field is often referred to as being substantial. However, precise information is difficult to find in the literature. Wood (1994) gives an account of rats in African agriculture. He points out that “*the rice agro-ecosystem is favourable to the build-up of populations of grassland rats, which are often the worst pest of the crop, with a potentially devastating impact*”. While ripe grain constitutes a rich food source, cutting of growing plants by rats is the major source of losses. Species involved in field damage of rice in Nigeria are the Nile rat (*Arvicanthis niloticus*), the shaggy rat (*Dasymys incommutus*) and others that remove seeds including the house mouse (*Mus musculus*) and the roof rat (*Rattus rattus*). The participants of the stakeholder forum also mentioned rodents as pests that are particularly difficult to contain because of their nocturnal habits. Farmers in the fields confirmed regular rodent attack. During the visit to a demonstration plot of the Agricultural Graduate Association of Nigeria (AGAN) in Washe the rodents could be observed moving in the field.

Different **bird** species feed on rice grains when the time of harvesting is approaching. According to Mey & Demont (2013) rice is mainly affected by birds in the humid zone. The most serious pest birds are gregarious and migratory ones, such as the weaver birds red-billed Quelea (*Quelea quelea*), village weaver (*Ploceus cucullatus*), black-headed weaver (*Ploceus melanocephalus*). The pest status of red-billed Quelea can be explained by its habits (gathering in flocks of several million birds and breeding in colonies that can cover more than 100 hectares with about 30.000 nests per hectare). The Invasive Species Compendium Datasheet of CABI (2014) provides details on Quelea biology. They breed usually in thorn trees such as *Acacia* spp. Their migratory habits in Nigeria include southward travel from the breeding sites in the Northern States at the start of the rains in June - July. Other important bird pest species in West Africa are geese such as spur-winged goose (*Plectropterus gambensis*) and knob-billed goose (*Sarkidiornis melanotos*), and also golden sparrow (*Passer luteus*).

The ranking of the importance of pests made by farmers and extension agents during field visits showed that in Niger and Kogi States Quelea birds were perceived as the most destructive pest, followed by field rodents. Several participants of the stakeholder forum confirmed that heavy damage occurs when Quelea birds appear in large numbers from late spring on. Insects apart from migratory locusts were considered as a minor issue only. The fields visited during the consultancy only showed some stem borer damage here and there (Annex 4; photos 4974, 4997 – 4999, 5150). The African rice gall midge was rarely ever mentioned. The same applies to the stalk-eyed fruit fly. Termites were considered by farmers to be destructive in rainfed rice cultivation. In Idah, a field trial showed considerable damage by termites in plots that had been mulched as compared to plots without mulch (Annex 4; photos 5221 – 5225). Farmers in Washe also reported ant damage from a nursery (but maybe they meant termites). They also claimed that frogs were damaging the crop which must definitely be an error as all frogs are predators.

In Washe many panicles had grains completely eaten or stripped off (Annex 4; photos 4977 - 4980). The farmers and extension agents attributed this damage to grasshoppers that had never been observed directly. It appears more probable that birds (which had not been observed, either) and village goats that could be observed in the field (Annex 4; photo 4969) were causing this damage.

2.4 Post-harvest issues

Along the post-harvest value chain, several stages involve losses (harvesting, transportation, threshing, parboiling, storage, milling, and commercialization). In this study only losses that relate to pests and/or affect human health have been considered. A recent overview of post-harvest losses of rice has been executed by Oguntade (2014) in which all stages of the rice value chain have been considered. The author estimates total post-harvest losses of 24.9 % occurring all along the rice value chain including about 6 % storage losses. It is not evident whether issues such as contamination of rice by rodents during storage (e.g. through droppings or urine) have not been sufficiently taken into consideration so that actual losses may probably be still higher than indicated in the study by Oguntade.

Apart from the topics described in sections 2.4.1 – 2.4.3, parboiled paddy drying on the road was observed between Bida and Washe (Annex 4; photos 5046 - 5050) which most probably does not only result in contamination with dust and exhaust fumes but also in mechanical losses (breaking of grains) because of numerous vehicles passing over the produce (Annex 4; photo 5082).

2.4.1 Post-harvest insect pests

Literature reviews confirm that major cosmopolitan rice post-harvest insects have been reported from Nigeria, too (Hagstrum & Subramanyam (2009). The most common and most devastating pests found in stored rice include the species listed in table 1.

Table 1: Post-harvest rice insect pests reported from Nigeria

Scientific name	Common name
<i>Carpophilus hemipterus</i>	Driedfruit beetle
<i>Corcyra cephalonica</i>	Rice moth
<i>Cryptolestes ferrugineus</i>	Rust-red grain beetle
<i>Lasioderma serricorne</i>	Cigarette beetle
<i>Latheticus oryzae</i>	Longheaded flour beetle
<i>Plodia interpunctella</i>	Indianmeal moth
<i>Rhyzopertha dominica</i>	Lesser grain borer
<i>Sitophilus oryzae</i>	Rice weevil
<i>Sitotroga cerealella</i>	Angumois grain moth
<i>Stegobium paniceum</i>	Drug store beetle
<i>Tribolium</i> spp.	Flour beetle species
<i>Trogoderma granarium</i>	Khapra beetle

These pests can cause considerable losses in quantity but quality changes such as off-odors, damaged grain, excretions, presence of dead insects and insect parts or subsequent secondary damage including in particular mould growth with mycotoxin production constitute much more serious problems.

Post-harvest loss issues were mentioned repeatedly in the stakeholder forum but there were no details provided in terms of pests involved and significance of damage. Obviously farmers do not store rice over longer periods before sale because of lack of adequate storage structures. The farmers' stores and processing facilities visited did not show any traces of stored product insect attack. However, due to the construction of most facilities and inadequate post-harvest protection measures attack is possible at any time. Some photos from Annex 4 may illustrate this point:

- Photos 5011 - 5016: Small village rice processing unit in Washe with free access for pests and much processing residues that can serve as hiding place and food for weevils and moths
- Photos 5018 – 5020: Rice warehouse in Washe with bags stored in disorder - proper pest monitoring and management cannot take place in such conditions
- Photos 5025, 5026: Open air processing unit in Washe attracting pest insects with processing residues
- Photos 5250 – 5263: Rice processing cluster in Idah with buildings that are by no means rodent-proof; unprotected product and processing residues available in large quantities
- Photos 5273, 5274, : Examples of farmers' rice storage in Abejukolo with bags in disorder
- Photo 5280: Rice stored in open bags in Abejukolo.

2.4.2 Commensal rodents

Lund (1994) indicated that storage facilities in developing countries most often provide easy access to rodents. Funmilayo (1980) reported that the multimammate rat (*Mastomys natalensis*) live “inside piles of rice panicles harvested and left in the field and to consume a substantial proportion of the fruits before the panicles are threshed and removed to the store”. According to the same author, many more species occur but apart from the multimammate rat only the roof rat (*Rattus rattus*) and the giant rat (*Cricetomys gambianus*) have been captured “consistently and in appreciable numbers during extensive trapping in infested mills, warehouses, commercial stores and domestic pantries”. Post-harvest losses were estimated to be around 5 %. Apart from economic damage done by feeding on stored products such as rice and contaminating these with feces and urine health hazards to humans must be taken into consideration. Amongst the more than 100 contagious diseases transmitted by rodents only Lassa fever shall be mentioned here, a severe acute viral haemorrhagic fever transmitted by the multimammate rat (cf. CDC Fact Sheet Lassa Fever, no year).

Practically all farmers visited confirmed that commensal rodents were a big problem in storage. Rodent traces (droppings) could be observed (Annex 4; photo 5272) and

Several rats were found in a box containing all kind of stuff and standing in a corner of the rice mill of the Agricultural Development Project in Lokoja (Annex 4; photos 5170, 5171, 5168, 5172, 5173, 5177). Certainly the open construction (Annex 4; photos 5167, 5184, 5189) does not provide any obstacle to rodent access and attracts pigeons at the same time (Annex 4; photos 5185, 5186, 5191, 5192). Furthermore, spilled paddy below the machines (Annex 4; photos 5194, 5197) and elsewhere as well as open bags (Annex 4; photo 5180, 5181) and processing residues aggravate the problem (Annex 4; photos 5182, 5183, 5187 - 5190).

2.4.3 Moulds and mycotoxins

While aflatoxin (AF) issues have become a worldwide concern since several decades especially in crops such as maize and groundnuts, rice in Nigeria was not much in focus so far. However, research undertaken in Niger state which was published in 2011 and summarized by Makun & al. (2012) is alarming: "*Makun et al. (2011) demonstrated a 100 % prevalence of AF in Nigerian rice at unsafe levels (range: 28 - 372 µg/kg) (...), and also showed critical contamination by ochratoxin A (OTA) and presence of deoxynivalenol (DON), fumonisins (FB) and zearalenone (ZEA) at trace levels*". As far as consumer hazard is concerned it is helpful to have a look at maximum residue levels such as the ones included in European Commission Regulation (EC) No 1881/2006 which is 5 µg/kg for AF B₁ in rice and 10 µg/kg for total AF.

As already stated in the previous section, insect attack is one of the boosting factors for fungi growth on grain such as rice, alongside with humid conditions (e.g. insufficient crop drying) and other factors.

During the field observations there was no indication of mould in stored paddy or rice. Low relative humidity during the time of harvesting and proper drying of the rice apparently help to minimize this problem in the regions visited by the consultant.

3. Current weed, disease and pest management, control practices and pesticide application by smallholder rice producers in different cropping seasons and production areas

3.1 Weed management

3.1.1 Weed management in lowland rice

The WARDA production handbook for lowland rice published by Nwilene & al. (no year) contains recommendations for weed control that are summarized here. Weed prevention starts from soil preparation. In areas where perennial weeds prevail, it is recommended to disc plow the field immediately after harvest in November/December to expose the weed rhizomes (roots) to the sun. Then the field should be flooded for about 2 weeks to kill the weeds. After two weeks the water can be removed and basins can be prepared. Bunds around the field retain water and at the same time suppress weeds.

The following recommendation applies to wet bed nurseries: About 5 days after sowing nursery beds should be kept flooded to a depth of 2 - 3 cm. The water depth should gradually be increased to about 5 cm to prevent weeds and also ensure easy pulling of seedlings. Always use good quality seeds with no contaminants such as weed seeds.

Hand weeding in the rice field can be performed about 14 - 20 days and again 30 - 40 days after transplanting the seedlings. However, negative social impact (increased workload in particular for women and children) requires preferred use of alternatives such as mechanical weeding or herbicides.

In case of direct seeding, herbicides have been recommended. An overview of herbicide applications is given in section 2.1.3 of this study.

Participants of the stakeholder forum stated that herbicides are preferred by farmers as manual weeding is very tedious. There seems to be a simple mechanical weeder that has been developed in the country but apparently it is not easily available.

Farmers in all locations visited confirmed that they use herbicides regularly. General practice includes use of pre-planting herbicides (products containing glyphosate or paraquat in the first place) and in case of need, also post-emergence herbicides including 2,4-D and propanil.

3.1.2 Weed management in upland rice

Oikeh & al. (no year) have published a WARDA production handbook for upland rice that includes weed management recommendations. For newly cleared fields in the forest area, harrowing two weeks after ploughing is recommended to allow the weeds to die.

In addition, some recommendations made in the previous section also apply such as use of good quality seeds with no contaminant weed seeds. Growing rice after dual-purpose grain legumes in rotation can be practiced to reduce parasitic *Striga* weeds (witch weeds).

Furthermore, thorough hand weeding is proposed: first within 2 to 3 weeks after emergence using a hoe (the earlier the better) with a second weeding 6 to 7 weeks after emergence, before panicle initiation and second N topdressing, to minimize the effect of the weeding process on panicle initiation. If necessary, a third weeding is required. As already mentioned in the previous section, negative social impact has to be taken into account, in particular because hand weeding can be rather ineffective, especially for controlling many of the perennial weeds (e.g. *Cyperus* spp.).

Information on chemical weed control has been summarized in the next section.

3.1.3 Synthesis on weed management in rice

The most recent comprehensive overview on weed management in African rice has been provided by Rodenburg & Johnson (2013). It contains a summary on common weed control practices highlighting advantages and disadvantages (see table 2).

From the point of view of social and environmental sustainability, some of the methods listed in the table do not appear suitable for promotion by the CARI program. In some aspects, the assessments given by the authors of the table also require comments. In particular part of the disadvantages listed can be seen as challenges for R&D rather than disadvantages. The CARI program is in a good position to promote better availability of equipment and other inputs and to provide knowledge.

Hand weeding can definitely not be a general solution with regard to social equity. In special cases such as seedbeds where the surface is comparatively small hand weeding may be a feasible option but the amount of work required for bigger surfaces can be applied in much better ways (e.g. increased school attendance of children or income generating activities of adults involved).

Pre- or post-season fires have mainly negative impact on the natural environment (release of environmental contaminants such as carbon dioxide and methyl bromide; negative impact on biodiversity) and should be discouraged altogether.

Improved rice cultivars are one of the prerequisites for increase of yields. Their performance can be considerably boosted in a sound rice IPM system as suggested in the last line of table 2.

Table 2: Overview of weed control practices in rice in Africa (After Rodenburg & Johnson, 2013)

Method	Target systems	Advantages	Disadvantages	R&D priority
Hand weeding	Mainly in rainfed systems	Highly effective; prevents weed seed production; important in providing 'spot control' of problem weeds	Labour intensive; negative effects on women and children	Low
Controlled flooding	Irrigated systems	Controls most weed species	Requires large amounts of water, good infrastructure and equipment	Medium
Pre- or post-season fires	Across systems	Can reduce seed production and soil seed bank	Ineffective for species like <i>C. odorata</i> and <i>I. cylindrica</i> ; can cause soil degradation	Low
Mechanical weeding	Across systems	Effective; prevents weed seed production; relatively quick	Requires availability of equipment; less effective in controlling weeds in the crop row	High
Chemical weed control, including resistance management	Mainly in larger scale irrigated systems	Effective when applied well; labour-saving	High market dependence; requires equipment and know-how; risk of development of herbicide-resistant weeds	High
Improved rice cultivars (weed competitive or parasite resistant)	Upland systems, direct-seeded lowland systems, but not broadly applied	Effective, cheap and labour-saving	Requires combination with other genetic traits (e.g. grain quality, stress resilience)	Medium
Crop rotations, intercropping, improved fallow	Mainly in rainfed upland systems	Provides basis of resilient systems	Requires land area; risk of competition with rice crop	Medium
Integrated weed management	General	Effective and putatively sustainable	Labour and knowledge intensive	High

Chemical weed control shows a lot of promise, too, within the framework of sustainable rice IPM. Table 3 provides an overview of common active ingredients currently used. However, many of these substances have a range of undesirable features with regard to long-term health effects and environmental side-effects. This is still a big challenge for CARI as herbicide use is essential for raising productivity in rice cultivation but the range of registered and available active ingredients in its four target countries is very much limited and includes mainly products that are problematic to some extent (see also the comments in Chapter 7).

Combinations of active ingredients are often used to control a wider range of weed species. Farmers should never prepare mixtures of their own but use products containing a mixture of active ingredients formulated by the manufacturer. Dosage rates and other details of application provided on the product label should always be adhered to strictly.

Certain weeds require more attention than others because they are very tough and difficult to control, namely wild rice, sedges, Cogon grass (*Imperata cylindrica*) and witch weed (*Striga*). In this case, good agricultural practice can be very supportive (cf. recommendations given above in this chapter and in table 16).

Table 3: Common rice herbicides and their application range (Adapted from Rodenburg & Johnson, 2013; information in the last column taken mainly from Greenpeace, 2010 and GESTIS database)

Time of application	Active ingredient	Production system (lowland/upland rice)*	Target weeds*	Species with known resistance	Major hazards and recommendations
Pre-emergence	Fluorodifen	L/U	B	-	Very toxic for fish
	Oxadiazon	L/U	B, S, G	<i>Oryza barthii</i> , <i>Commelina benghalensis</i> , <i>Chromolaena odorata</i> , <i>Eclipta prostrata</i>	Carcinogenic; reproductive toxicity; high aquatic toxicity; bioaccumulative; persistent; not recommended because of severe hazards
	fla	L/U	G, S, B	<i>Leersia hexandra</i> , <i>O. barthii</i> , <i>C. benghalensis</i> , <i>Euphorbia heterophylla</i>	High aquatic toxicity; bioaccumulative; persistent; not recommended because of environmental hazards
Pre-/Post-emergence	Bensulfuron	L	B, S	-	Only moderate hazards for human health and the environment
	Butachlor	L	B, G, S	<i>L. hexandra</i> , <i>O. barthii</i> , <i>Rottboellia cochinchinensis</i> , <i>C. benghalensis</i> , <i>E. prostrata</i> , <i>Trianthema portulacastrum</i>	Because of carcinogenic hazard and known resistances in different weed species not recommended
	Glyphosate	L/U	B, S, G	-	High aquatic toxicity; high persistence; use requires precautions to avoid water pollution
	Paraquat	L/U	B, G, S	-	Low ARfD; very high dermal toxicity; neurotoxic; associated with Parkinson's disease; high aquatic toxicity; high persistence; not recommended because of high human health hazards
	Piperophos	L	G, S	<i>Fimbristylis littoralis</i> , <i>Eleusine indica</i>	Because of high neurotoxic hazard not recommended
	Quinclorac	L	G	-	Immunotoxic and persistent
	Thiobencarb	L	G, S, B	<i>L. hexandra</i> , <i>O. barthii</i> , <i>R. cochinchinensis</i> , <i>Ageratum conyzoides</i> , <i>C. benghalensis</i> , <i>E. prostrata</i>	Because of high aquatic toxicity, high persistence and known resistances in different weed species not recommended
Post-emergence	2,4-Dichlorophenoxyacetic acid (2,4-D)	L/U	B, S	<i>C. benghalensis</i> , <i>E. heterophylla</i>	Associated with Parkinson's disease, neurotoxic and reproductive toxicity; toxic to aquatic life with long lasting effects; not recommended
	Bentazone	L	B, S	-	High immunotoxicity; high persistence; use with special care to minimize aquatic hazards
	MCPA	L	B, S	-	Because of high neurotoxic hazard and high aquatic toxicity not recommended
	Molinate	L	G, S, (B)	<i>Ischaemum rugosum</i>	Because of high reproductive toxicity, high neurotoxic hazard and endocrine-disrupting effects not recommended
	Propanil	L/U	G, (B,S)	<i>O. barthii</i> , <i>R. cochinchinensis</i> , <i>C. benghalensis</i> , <i>E. prostrata</i> , <i>T. portulacastrum</i>	Low ADI; carcinogenic; very high aquatic toxicity; toxic for birds; endocrine-disrupting effects; to be used with care to avoid negative environmental effects
	Triclopyr	U	B, S	-	Low ADI value

L = lowland rice; U = Upland rice; B = broadleaved weed; G = grass; S = sedge

3.2 Management of diseases

Séré & al. (2013) reported on surveys in Burkina Faso which indicated that intensifying rice cultivation through fertilizer application and use of high-yielding, but susceptible, rice varieties may lead to increased yield losses due to blast, reducing an important part of the benefit created by intensifying rice cultivation. This is an important observation which emphasizes the importance of a sound IPM concept for intensification of rice growing and increasing farmers' incomes. One of the cornerstones of such an IPM approach are tolerant varieties: "*Genetic control receives the most attention among the control measures to be used against rice pathogens, because it is the easiest method for farmers to adopt and the principal component of the IPM strategy*" (Séré & al., 2013). Rice varieties with tolerance against RMYV include LAC23, Moroberekan, IR 47686-1-1 for direct seeded rainfed lowlands; and WITA 9, WITA 11 and Gigante (tete) for irrigated lowlands. Use of traditional *Oryza glaberrima* varieties such as TOG 5674, 5675, 5681, 7235, 7291, and others has also been recommended.

Environmental factors influence the expression of blast, including temperature, humidity, leaf wetness, nitrogen fertilization and drought. Crop management practices that minimize the negative impact of such factors can be used in blast management (Séré & al., 2013).

In their production handbooks Nwilene & al. (no year) and Oikeh & al. (no year) give further recommendations for disease control in lowland and upland rice adapted to the situation in Nigeria. Good cultural practices limit infection of blast and RYMV:

- Destroy rice residues after harvest and the ratoons that harbour RYMV and insect vectors.
- Change nursery sites.
- Transplant seedlings early with reduced plant spacing before the outbreak of the chrysomelid beetle *Trichispa sericea*, (a RYMV vector).
- Practice synchronous planting.
- High nitrogen associated with low potassium can increase blast damage → practice appropriate fertilising.
- Split application of nitrogen is better than one application to reduce blast damage.
- Reduction of fertilizer application (e.g. urea) on attacked plots.
- Remove surrounding weeds to destroy alternate hosts of RYMV.
- Early and double weeding to reduce the weed reservoir of the virus and insect vectors.
- Rogueing of infected plants and immediate replanting.
- Withhold irrigation water between plantings to provide a period without cultivation to restrict the build-up of virus infection and insect population.

Clean and healthy seeds should be used by all means, combined with a treatment 1 – 2 days before sowing with a mixture of insecticide and fungicide blast to reduce infestation. The following examples have been provided in the handbooks*:

- Thiamethoxam (20 g/l) + difenoconazole (2 g/l) + metalaxyl-m (20 g/l) at the rate of one sachet per 4 kg seeds
- Carbosulfan + carbendazim + metalaxyl-m
- Thiram + chlorpyrifos-ethyl

*Comments on special hazards of the products listed above:

- Thiamethoxam has been banned in the EU in 2013 because of high toxicity for aquatic organisms and bees so that its use cannot be recommended any longer.
- Difenoconazole has a low ADI (Acceptable Daily Intake), is carcinogenic and very persistent.
- Metalaxyl-m has suffered several severe cases of resistance of target fungi

- Carbosulfan has been banned in many countries (including the EU) because of a couple of undesirable features. It has a low Acute Reference Dose (ARfD), neurotoxicological effect, and it is bioaccumulative. Furthermore, it has elevated toxicity for aquatic organisms, birds, bees, and rainworms. For human health and environmental reasons this active ingredient should be replaced by less harmful products.
- Carbendazim has a very low ARfD; high reproductive toxicity; is mutagenic and very toxic for aquatic organisms and rain worms
- Thiram has a very low ARfD, is carcinogenic and neurotoxic; residues are often found in food in the EU
- Chlorpyrifos-ethyl is neurotoxic, very toxic for aquatic organisms and bees, and bioaccumulative and should not be used any longer because of its multiple hazards, in particular for the environment.

It is preferable to buy dressed seeds that have already been treated with appropriate pesticides instead of performing seed dressing on-farm because the pesticides used for this purpose have high contents of active ingredients and thus are more hazardous for applicators than pesticides sprayed in the field.

In areas conducive to fungal diseases, spraying of mancozeb (80 %) at 1.0 kg a.i./ha or benomyl (50 %) at 1.5 kg a.i./ha, in 500 liters of water to control rice blast, brown spot and grain discoloration has been recommended in the aforementioned production handbooks; if the damage is severe, spray again after 15 days.*

*Comments on special hazards of these substances:

- Mancozeb is carcinogenic, has high reproductive toxicity is neurotoxic and associated with Parkinson's disease; residues have been frequently encountered in food in the EU; it is a problematic substance to be replaced by less hazardous fungicides.
- Benomyl is characterized by reproductive toxicity, mutagenic effect, very high aquatic toxicity; residues are frequently encountered in food in the EU; not to be recommended

According to Séré & al. (2013), benomyl, edifenphos, and tricyclazol have been identified as efficient fungicides in Africa.*

* Comments on special hazards of these substances:

- Benomyl: see comment above!
- Edifenphos is neurotoxic
- Tricyclazol is toxic for birds and very persistent

One of the preconditions for integrated RYMV management is vector control, i.e. prevention and, if feasible, treatment of vector insects such as chrysomelid beetles and grasshoppers.

Apart from tolerant varieties, cultural practices play an important role in blight IPM (burning crop residues after harvesting heavily infected fields; destroying the surrounding weeds that serve as a reservoir of the pathogen; prevention of spreading RYMV diseases from seedbed or weeds; proper management of fertilizers, particularly nitrogen).

Field observations made during the consultancy indicate that cultural practices (destruction of crop residues after harvest in the first place) are the most common practices to control diseases while fungicide use (products containing mancozeb) is not widespread.

3.3 Pest management

The principle written down by Nwilene & al. (2013) summarizes the current attitude concerning IPM: *“Integrated pest management has evolved from pesticide-abatement strategies into analytical approaches to understand pest status within production systems in order to make informed decisions on appropriate management options that incorporate social, economic, gender and environmental issues”*.

In this context a table published by Oerke & al. (1994) is helpful that highlights the importance of major production and loss factors in rice:

Table 4: Cultural profile of lowland rice and upland rice*

*Importance of diseases, pests and weeds is indicated in a scale ranging from + (slightly important) to ++++ (very important)

	Lowland rice	Upland rice
Usage of agrochemicals	Medium to high	Low
Yield potential	High	Low
Stability of yield	High	Low
Importance of host resistances	Very important	Less important
Diseases	++ to +++	++ to ++++
Insect pests: <ul style="list-style-type: none"> • Specificity • Soil insects • Epigeous insects 	Monophagous No importance ++++	Polyphagous ++++ ++
Weeds	++	++++
Birds	+	+++
Rodents	+++(+)	+

This information can be used to determine preferences for IPM tools to be applied in lowland and upland rice, in particular, as there are some striking differences between the cultural profiles. Weeds and soil insects are much more important in upland rice than in lowland rice. The opposite is observed for epigeous insects, i.e. insects living above ground. Host resistance, i.e. selection of tolerant varieties is more important for lowland rice than for upland rice. Likewise, agrochemicals including pesticides have more potential in lowland rice than in upland rice.

Nwilene & al. (2013) gave an overview of rice pest management in Africa and stress the importance of growing tolerant rice varieties stating that *“... there are both upland and lowland NERICA varieties and traditional O. sativa varieties that are resistant or tolerant to some key pests of rice in Africa”*. The production handbook of Nwilene & al. (no year) also includes recommendations for pest control in lowland rice with regard to the special situation in Nigeria.

Smallholder farmers in Africa used to and still rely on traditional pest management methods, mainly botanical pesticides. While it has been well investigated which botanicals and application techniques really work, success will depend on combining these methods with modern standard IPM methods and recent research results in a way that provides high and stable yields.

The following paragraphs highlight recommended management options for major pests or group of pests.

Stalk-eyed shoot fly (*Diopsis* spp.) management includes cultivation of the tolerant variety WAB 1159-2-12-11-6-9-1-2 with highly hairy leaves can trap *Diopsis* larvae.

Cultural practices such as early sowing, narrow spacing of plants and maintaining weed-free fields should be observed to minimize *Diopsis* infestation. Synchronized planting over a large area allows the most susceptible stage of rice to escape from *Diopsis* damage.

African Rice Gall Midge (AfRGM) Management:

For AfRGM-affected areas tolerant rice variety can be used:

- Cisadane (FARO 51), BW348-1, Leizhung, and others
- traditional *Oryza sativa* varieties such as TOS 14519
- tolerant lowland NERICA varieties, e.g. NERICA L-25, NERICA L-19, NERICA L-29, NERICA L-49
- traditional *Oryza glaberrima* varieties such as TOG 7106, 7206, 7442, 6346, 5681, and others

Early and synchronized planting of rice fields can minimize damage as compared to late planting. Narrow spacing such as drilling should be discouraged because it provides a suitable micro-environment for the survival of the exposed life stages of AfRGM. Alternative host plants such as rice ratoons, volunteers and the weed *Oryza longistaminata* should be destroyed. Moderate levels of fertilizer (e.g. 60 kg/ha) should be used and applied in split doses. Movement of seedlings should be discouraged because such seedlings can be infested by AfRGM in the nursery.

Carbofuran* has been proposed at 1 kg a.i./ha in the nursery beds one week before uprooting.

*Carbofuran is a highly toxic substance that has been banned in many countries (e.g. since 2007 in the EU and since 2009 in the US). It is characterized by a low Acute Reference Dose (ARfD), neurotoxicological effect, and elevated toxicity for aquatic organisms, birds and bees. For human health and environmental reasons this active ingredient should be replaced by less harmful products.

Oikeh & al. (no year) provided the recommendations given below to control **stem borers** in upland rice:

- Use of tolerant rice varieties such as LAC 23, ITA 121, TOS 4153, NERICA 1, NERICA 2, NERICA 4, NERICA 5, and NERICA 7
- Management of stubble by burning, plowing and flooding after harvest destroys diapausing larvae of the African white borer (*Maliarpha separatella*)
- Strip- and inter-cropping of maize with NERICA rice varieties was found to be effective in reducing stem borer damage on rice because maize and rice share some common stem borer species.
- Protect beneficial insects in the field (predatory beetles such as Carabids, reduviid bugs, dragonflies, spiders and parasitic wasps)

Termite control may include traditional methods such as use of bamboo stems, smoking the termite nest, use of salt, and flooding termite nests with water. Application of red palm oil mixed with pawpaw is an indigenous biological control practice. It is said that the mixture attracts soldier ants that attack and drive away the termites.

Biopesticides such as neem seed oil and neem powder (22 liters of neem seed oil concentrate in 220 liters of water/ha and 800 kg/ha, respectively) and powdered tobacco are effective against termites

because they serve as potential replacement for problematic chemical pesticides, such as Carbofuran which has already been banned in several countries (see remark above).

The entomopathogenic fungus *Metarhizium anisopliae* is an effective biological control strategy against termite attack on upland rice (2 grams spore powder mixed with 60 cm³ of wood powder or saw dust. Put mixture in a hole of 3 cm depth and cover with a small quantity of saw dust to protect spores against sunlight). It is recommended to check the availability and performance of the commercial *M. anisopliae* product Green Muscle developed by IITA.

Rice varieties such as LAC 23, NERICA 1, 2, 5, 14 and others have proven to be more tolerant towards termite attack than others.

Nwilene & al. (no year) suggested incorporating carbofuran at the rate of 2.5 kg a.i. per hectare into planting row in areas with termite and nematode problems. Here again the undesirable negative features of the active ingredient are prohibitive to further use (see the comment on carbofuran above).

Most of the recommendations provided by Nwilene & al. (no year) to control rodents and birds are problematic. Efforts to scare **birds** do not have any lasting effect unless scaring is done permanently by people (usually an additional workload for children).

Red-billed Quelea ecology and control have been thoroughly studied in Nigeria during the 1970s in a GTZ project (Conert, 1982). While different control methods that were practiced before, were not satisfactory for various reasons, systematic aerial ULV spraying of nesting and sleeping sites with fenthion* as a large-scale operation proved to be effective. According to Emechebe & al. (2013), fenthion is still used by state agents for this purpose, as well as dichlorvos (DDVP)**. This observation could be confirmed on the ADP (Agricultural Development Project) site in IDAH where the empty fenthion drums left over from a recent aerial control campaign were stored in the open air. Quelea birds should in fact be monitored and controlled at the sites of breeding where they colonize in large numbers. Attempt to control them outside their breeding areas often fail as the birds appear suddenly and can escape easily.

*Fenthion has a very low ARfD, is neurotoxic, very toxic for aquatic organisms and bees, and bioaccumulative

**Dichlorvos is characterized by low ARfD, high acute toxicity, neurotoxicity, very high aquatic toxicity and very high toxicity for birds and bees

According to Nwilene & al. (no year), possible measures against **rodents** include leaving an uncropped margin of 1 - 2 meters around fields. Distribution of poisoned bait in containers in the uncropped field margins and alleys may lead to intoxication of non-target organisms including farm animals and children. Mouse and rat traps generally work but in many cases showed comparatively little impact in the field.

Posamentier (1989) highlighted the general control aspects listed below:

- Importance of continuous rodent monitoring to become aware of an infestation and its extent as early as possible
- Hygiene in human dwellings and in the field (withdrawal of food sources), also called "habitat management"
- Mechanical control methods including flooding, digging out burrows, and trapping (in case of low rodent population)
- Treatment of larger areas simultaneously to minimize rodent migration from treated to untreated areas – this approach requires good cooperation between farmers
- Exchange of experience between farmers to motivate them for joint action.

Furthermore, Posamentier (1989) recommends baiting with rodenticides using attractive bait in stations. However, as compared to the situation in the eighties, many parameters of rodent baiting have changed during the last years. In particular, use of second generation anticoagulants has been strictly limited in European Union member states because of they are considered to be persistent in the natural environment, bioaccumulative and toxic or, depending on the substance, even very persistent and very bioaccumulative. Limitations include use of most rodenticides by specially trained experts only, exclusive use of ready-made bait (no preparation of attractive bait with concentrates of active ingredients), and other risk mitigation measures.

As a consequence, only active ingredients that do not fall under these restrictions can be recommended for use in field rodent control. In practice, no product that would fulfil these requirements is registered and available in Nigeria.

Field observations made in Nigeria during this study can be summarized very briefly:

- Contrary to the current opinion that can be found in many publications, classical rice pests such as stem borers, AfRGM and stalk-eyed fruit flies are not in the focus of pest control measures of rice farmer in Kogi and Niger States. If a treatment is required they often recur to products containing λ -cyhalothrine. In Wushishi famers said that insects in general are only a minor problem but at the same time they declared to spray cypermethrine two times during the cropping season irrespective of pest occurrence. They said that AfRGM appears 21 – 24 days after transplanting.
- Quelea control involves mainly scaring of the birds using scarecrows, suspended video tapes or similar material that move in the wind and/or produce sounds (Annex 4; photo 5131). Often boys or women are involved in scaring the birds actively. These methods have been considered to be of little use by the farmers themselves and, if hired labour is employed, as rather costly as control is required from early morning until the evening (6 am – 6 pm approximately during up to 30 days. Covering the crop with fishing nets has been applied successfully but can only be practiced if the fields are not too large (Annex 4; photos 5140 – 5145, 5150).
- No systematic control approach against rodents could be found in the field; sometimes baiting with more or less questionable pesticides has been reported. Brodifacoum bait is available at pesticide shops. In Washe use of nets where rodents entangle was tried successfully (Annex 4; photo 4987).

3.4 Post-harvest loss prevention

According to Oikeh & al. (no year) rice varieties such as NERICA 4 and WAB 56-104 are tolerant against stored product insect attack.

Nwilene & al. (no year) highlight good storage conditions. Loss prevention is based on the following conditions:

- Store only dry (maximum 13 – 14 % moisture content) and well cleaned rice
- Storage at 65 % relative humidity or less is ideal to prevent mould growth
- Temperatures should be as low as possible – provide good aeration
- Inspect rice regularly (if possible, weekly) during storage.

There are plants and plant extracts that deter pests but some of them (like chilli peppers) may change the smell or taste of the rice. Activated silica gel powder dehydrates insects in the bulk.

Not much systematic stored product pest management could be observed in the different stores observed. Some farmers take care that the store is rodent proof. The rice warehouse visited in Bida with solid construction and door that close well is an example. Storage on pallets is being introduced and all walls will be plastered (Annex 4; photos 5028 – 5032, 5034).

Airtight containers for grain storage lead to suffocation of insects but care must be taken that the rice to be stored is well dried and that the container is not exposed to the sun to avoid temperature fluctuations with subsequent condensation of humidity inside and mould growth. A very promising approach is the PICS triple bag consisting of two layers of airtight plastic material plus an outer layer made of woven plastic material which was initially developed for cowpea storage by Purdue University researchers in a project funded by the BMGF (Purdue Agriculture, no year). It was reported that this bag conserves the rice very well if it is well closed because of oxygen depletion inside due to natural respiration processes. (Annex 4; photo 5277 – a sample is available in the project). Systematic evaluation of its use within the CARI program and broad distribution is highly recommended. The cost of the bag is very low (₦ 300 - 400) as compared to normal grain bags which cost about ₦ 250.

Application of aluminum phosphide pellets or tablets was found to be widespread but cannot be recommended to untrained farmers as the phosphine gas that develops from the tablets is extremely toxic to human beings! Furthermore, phosphine application requires hermetic sealing with gas-tight sheets to be effective. Phosphine in any formulation should only be applied by well trained professionals!

Attention: phosphine application by untrained users can have severe consequences:

- Intoxication (mortal in the worst case)
- Survival of stored product pest insects
- Development of resistant insect strains.

Many farmers apply aluminium phosphide tablets under conditions that are particularly hazardous (Annex 4; photo 5271) such as pounding them and adding the powder to fish or bread as bait. Some farmers reported to apply phosphine once a month.

Apart from phosphine application, the use of DDVP for protection of stored rice was often mentioned by farmers. Obviously they often add the product in high quantities that are not determined in a systematic way. With regard to the substantial human health hazards involved (low ARfD, high acute toxicity, neurotoxicity), this practice should be discouraged by all means.

3.5 Pesticides used in rice production in Nigeria

An overview of pesticides registered and used in Nigeria is given by Emechebe & al. (2013). The most common pesticides used in rice production within the CARI framework are listed and briefly characterized in table 5 on the next page (information obtained from CARI staff members). Products that are also used by rice farmers but outside the CARI program are included in table 6 on the next page (information from CARI staff members and field surveys during the consultancy).

Products found in the market were mainly generics from China or India; some original products from international companies are also available (see Annex 4; photos 4915 – 4920, 4925 – 4926, 4930 – 4962, 5036 – 5045, 5064, 5065, 5075, 5077, 5267 - 5269). They generally carried the NAFDAC registration number on the label (Annex 4; photos 4932, 4944, 49650. Labelling was in most cases rather comprehensive (e.g. Annex 4; photos 4948 - 4954). The WHO acute human health risk

classification is indicated on some products (e.g. Annex 4; photo 4918) and lacking on others (e.g. Annex 4; photo 5077). Hazard symbols are generally present but often pretty small so that they do not catch the eye (e.g. Annex 4; photo 4926). Some labels were inadequate because of incomplete information or tiny characters.

Table 5: Pesticides used by rice farmers under the CARI program

Substance	Use	Chemical classification	EU status and comments
Bentazone	Herbicide against dicotyledons	Thiadizine	EU: registered; take care to avoid pollution of aquatic environments
Glyphosate	Broad spectrum herbicide	Phosphonate	EU: registered and widely used
Mancozeb	Broad spectrum fungicide	Dithiocarbamat	EU: registered and widely used
Propanil	Post-emergence herbicide	Anilide	EU: banned; one of the most frequently used herbicides in the US; use with care to prevent negative impact on the environment

Table 6: Characteristics of pesticides used by rice farmers outside the CARI program

Substance	Use	Chemical classification	EU status and comments
2,4-D	Post-emergence herbicide to control broad-leaved weeds	Phenoxy acetic acid	EU: registered until the end of 2015; because of multiple hazards to human health and toxicity to aquatic life with long lasting effects not recommended
Benomyl	Fungicide	Benzimidazole	EU: banned; because of multiple hazards for human health and the environment not recommended
Carbofuran	Broad spectrum insecticide, acaricide and nematicide	Carbamate	EU: banned; not recommended ; obsolete and particularly hazardous pesticide that should be banned in Nigeria
Cypermethrin/ λ -cyhalothrin/ benomyl	Insecticide/ insecticide/ fungicide	Pyrethroid/ pyrethroid/ benzimidazole	EU: depending on the isomere/registered/banned; mixture with multiple hazard features; in principle not recommended ; continued use temporarily accepted because of lack of viable alternatives in the Nigerian pesticide market and also because of limited need; identification/registration of alternatives is strongly recommended
Dichlorvos (DDVP)	Insecticide	Organophosphate	EU: not registered; multiple human health hazards; not recommended
Isazofos	Insecticide and nematicide	Triazole	EU: not registered
Paraquat	Broad spectrum herbicide	Viologen	EU: banned; because of several hazards to human health and environmental hazards not recommended
Phosphine (aluminium phosphide)	Post-harvest fumigant against insects	Anorganic gas	EU: registered for use by specially trained and licensed fumigators; not to be used by untrained farmers

Apart from the product label, most distributors for generic products, wholesalers and retailers do not provide any information on the pesticides supplied (e.g. material safety data sheets or detailed application information). Some pesticide distributors exhibit information posters on responsible use of pesticides, safety precautions and maintenance of sprayers published by CropLife International and others (Annex 4, photos 4927 - 4929). Syngenta Nigeria makes a difference in training pesticide distributors on correct and safe use of their products. They also started training farmers including field demonstrations (so far in 100 plots with a size of about one quarter of a hectare) distributed over 7 Federal States.

A more precise characterization of the pesticides in tables 5 and 6 with regard to special health and environmental hazards involved is provided in table 15 in section 5.4.

4. Estimation of threshold levels for main pest problems

Determining economic threshold levels for any weed, pest or disease in any crop anywhere in the world is definitely a challenge. Threshold levels depend, amongst others, on the factors listed below:

- Incidence of and damage caused by a given pest organism at a given time
- Simultaneous incidence of and damage by other pest organisms
- Availability and price of agricultural inputs
- Value of the crop at the time of sale.

Any of these factors may vary from year to year so that threshold limits may have to be adjusted permanently. Farmers' decisions on cultural practices and/or time of sale of the crop may have huge impact on the threshold level.

4.1 Published rice loss estimates

Fröhlich (1974) quoted worldwide loss estimates published by Cramer in 1967 that amount to 47 % of the potential rice yield. About 27 % of these losses were attributed to pests, 9 % to diseases and 11 % to weeds. In Africa, a total of 34 % loss was reported. Altogether opinions and estimates vary widely and there is also no real consensus on the most serious loss agents. Certainly severity of attack can vary widely according to circumstances such as climate, agro-ecosystem, rice varieties grown, cultivation methods and many other factors. Oerke & al. (1994) provided more detailed loss figures for African countries that are presented in the following sections of this report.

4.1.1 Losses caused by weeds

Rodenburg & Johnson (2013) provided some information on rice losses caused by weeds in Africa: *"If not controlled, weeds cause yield losses in the range of 28 – 74 % in transplanted lowland rice, 28 – 89 % in direct-seeded lowland rice and 48 – 100 % in upland rice (...). In West Africa, it has been shown that farmers can increase their rice yields by 15 – 23 % by applying relatively basic measures to improve weed control, such as bunding of fields to retain flood water, and timely interventions such as herbicide applications and hand weeding"*.

WARDA loss estimates caused by weeds (without control) and published in 1984 have been quoted by Oerke & al. (1994). They present also a wide range: 100 % in Gambia, 84 % in Ghana, 80 – 100 % in

Nigeria, 48 % in Senegal, 62 % in Burkina Faso, and 39 – 87 % Liberia. For Nigeria, more detailed information has been provided by the same authors. Losses ranged from 0.7 to 2.6 t/ha depending on varieties and conditions of cultivation. Losses were higher than 60 % in lowland rice and 90 – 100 % in upland rice. In Ghana it could be observed that the importance of weed infestation increased with continuous cultivation.

4.1.2 Losses caused by diseases

Séré & al. (2013) have published a couple of loss figures due to rice blast that are summarized in table 7.

Table 7: Rice yield losses caused by rice blast (after Séré & al., 2013)

Country	% Losses	Remarks
Benin	36 – 63	
Burkina Faso	1 – 22	In rainfed lowland, published in 2011
Burkina Faso	4 – 45	In irrigated systems, published in 2011
Burkina Faso	36 – 63	Published in 1981
Côte d'Ivoire	Up to 80	
Ghana	Up to 100	
The Gambia	Up to 100	
Nigeria	35 – 50	
Nigeria	100	In serious outbreaks
Sierra Leone	More than 80	
Togo	64 %	

Oerke & al. (1994) mentioned losses of 11.5 – 39.6 % due to rice blast in Nigeria.

For *Rice blast* relations between disease incidence and losses were given based on studies made by Mathur & al., 1964 (see table 8 on the next page). In this context it should not be forgotten that blast spreads as indicated in the name of this disease and control action should be taken fast after observation of its presence.

According to Séré & al. (2013), rice losses caused by RYMV vary between 10 – 100 %, depending on the time of infection and the rice variety. Oerke & al. (1994) mentioned 25 % of losses caused by RYMV in Niger.

A survey on bacterial blight carried out in several West African countries resulted in loss numbers of 2.7 – 41.0 % and a disease incidence of 70 – 85 % in farmers' fields (Séré & al., 2013).

Table 8: Relation between rice plants infested with rice blast and yield loss (after Mathur, 1964)

% rice plants infested by Rice blast	% yield loss
20	8.2
30	12.6
40	17.1
50	21.6
60	26.1
70	30.5
80	35.0
90	39.5

4.1.3 Losses caused by pests

Nwilene & al. (2013) quoted an estimation saying that rice yield losses due to field insect pests in Africa range between 10 % and 15 %, and in some years may exceed 90 %. Major pest insects and associated damage differ by region, by country by season, and by rice variety. Average stem borer losses in Nigeria were estimated to be 29.2 % (Oerke & al., 1994). Heinrichs & Barrion (2004) have compiled some estimations of losses caused by rice insect pests within a range of to 13 % - 22 % depending on the source. There is some evidence that losses in low-yielding countries are higher than in high yielding ones. A quantitative loss of 18 % was reported on farmers' stored rice in Benin over 4 months of storage (Nwilene & al., 2013). De Mey & Demont (2013) quote rice losses due to bird damage in humid areas of 19 % of the crop yield.

4.2 Available economic data and calculation of threshold limits

Economic data on pesticide application in rice production have been compiled by Shaibu (2011); they are also accessible in the publication of Ibitoye & al. (2012). The study describes economic issues related to pesticide use in rice farming in the Ibaji Local Government Area (LGA) of Kogi State. The study site was part of the Fadama II project funded by the World Bank which involved IPM and pesticide use. Fadama are seasonally flooded plains along Nigeria's major river systems where mixed cropping including rice and livestock production prevail. The sample surveyed (120 households) revealed that in Ibaji LGA, the majority of rice farmers (77 %) were female and average farm sizes were around 1 ha. Men were more involved in yam production and fishing. In the rice areas visited during the mission rice growing was mainly a business of male famers. Awareness of IPM (87.5 %) and rate of adoption (83 %) were high. Adoption of IPM was related to several factors including high cost of hired labour, profitability and convenience. The educational standard was comparatively low (32 % with no formal education and 39 % with primary education only). 47 % of the respondents to the survey had farming incomes < ₦ 100.000 while 53 % were above this limit. The average household size was indicated to be 5 members. Average rice yield was about 2.500 kg/ha worth ₦ 125.000 with a gross return of ₦ 68.500/ha. The Benefit Cost Ratio calculated by Shaibu (2011) was 1.95. Cost related to weed and pest management was specified by the author as indicated in table 9.

Table 9: Cost of IPM in Fadama rice farming in Ibuji LGA, Kogi per ha (after Shaibu, 2011)

Item	Quantity	Unit cost	Total cost
Weeding	7 MD*	₦ 500	₦ 3.500
Pesticide application	2 MD*	₦ 500	₦ 1.000
Bird scaring	5 MD*	₦ 500	₦ 2.500
Pesticides (insecticides?)	2 litres	₦ 700	₦ 1.400
Herbicides	6 litres	₦ 800	₦ 4.800

*MD = man days

Shaibu (2011) indicated that 120 hours of manual weeding was equivalent to 4 hours of herbicide application (corresponding to a reduction of labour cost from ₦ 7.500 to just ₦ 250). He came to the final conclusion that the amount spent on pesticides was positively correlated to farmers' output and significant at 1 % level. He considered Fadama rice farming using the IPM approach economically advisable. He recommended amongst others developing new technologies aimed at saving labour and increasing farm level productivity. The numbers for cost given by Shaibu (2011) are lower than the numbers obtained in the course of the current study which can be explained by an increase in cost since that time.

In the study of Oguntade (2014) numbers for pesticide application are given that have been included in table 10.

Table 10: Pesticide application cost in Niger and Kogi States per ha according to Oguntade (original numbers were given relating to average rice farm sizes (i.e. 2.49 ha for both states compiled; 3.10 for Niger and 1.83 for Kogi)

Item	Value for both States	Value for Niger	Value for Kogi
Quantity of insecticides applied (l)	1.55	2.23	1.17
Value of insecticides (₦)	1397	4982	1163
Quantity of herbicides applied (l)	7.81	9.38	4.79
Value of herbicides (₦)	7867	9561	4778
Cost of treatment (₦)	3643	3380	4343

In the Farmer Business School material developed by Matthes (2014) numbers for weed and pest control measures per ha have been provided that are well in line with information obtained during field surveys. These numbers are listed below:

- Cost of insecticide: ₦ 2500
- Cost of pre-planting herbicide (glyphosate): ₦ 4600
- Cost of post-emergence herbicide: ₦ 4400
- Spraying pesticides (2 MD at ₦ 800 each) ₦ 1600
- Chasing birds: ₦ 15000

There have been many approaches towards determining threshold limits for single or multiple species economic losses (e.g. Selvaraj & al., 2012, on multiple-species economic injury levels for rice insect pests) and even flexible thresholds using dynamic programming (Harper & al, 1994). The most comprehensive source for rice is the IRRI workshop report on crop loss assessment in rice edited by Pollard LR & E Cervantes (1990). Another rich source of information is the Rice Pest Surveillance

Manual published the Thai-German Plant Protection Programme (TG-PPP) in 1988. It contains, amongst other issues, an overview of crop loss assessment methods, a description of establishing and testing economic action thresholds and practical hints for sampling. In Chapter 3 (extension), the publication provides threshold limits for major rice pests such as stem borers and rice gall midge, for diseases including rice blast and for weeds. Certainly, these threshold limits cannot simply be used as such in the CARI program as framework conditions differ considerably (rice varieties grown, agro-ecological environment, prices for agricultural inputs, labour, sales price for rice harvested, etc.). But the way how thresholds have been determined can be used in Nigeria, too, to find appropriate numbers. The limits given in this publication (e.g. 20 % soil coverage by weeds) can nevertheless serve as a first orientation.

Dent (1991) provided an easily readable account on sampling, monitoring, forecasting, yield loss assessment, and economic thresholds.

The basic way of determining economic action thresholds can be described in a simple formula:

$$AT = \frac{C}{PDK}$$

AT = action threshold

C = cost of control measure

P = price of crop (per unit, e.g. hectare)

D = loss in yield without control (tons per hectare)

K = reduction in damage due to control measure

Preconditions for applying any method to determine a threshold value in a scientific way are close monitoring of incidence of the respective pest organism(s) and ability in operating formulae and models involved in calculating threshold limits. In many real world field situations both conditions do not exist.

This is why a simple and practical approach is proposed here that is based on average losses reported in the past and observed in farmers' field during CARI program execution and on reliable economic parameters such as guaranteed sales prices within contract farming schemes.

4.3 Proposals for threshold limits in the CARI program

Calculations or informed estimates using the formula in the previous section can be made if the following parameters are known:

- Published loss estimates, results of loss surveys, farmers' appreciations
- Knowledge of the relation between pest incidence/number of plants attacked/damage, etc. and losses
- Current prices for pesticides, application equipment, labor, etc.
- Rice price after harvest.

Following the TG-PPP (1988) approach preliminary limits can be proposed which have to be tested in the field and adapted if required taking into consideration changes that occur (e.g. planting of new varieties, change in agricultural practices, changes of prices for pesticides and harvested rice, etc.

It can be assumed that threshold limits should be pretty similar because average rice yields in Thailand were 2.04 t/ha between 1988 – 1990 (time of the TG-PPP publication) and in Nigeria

2.24 t/ha for irrigated rice, 1.44 t/ha for upland cultivation and 3.02 t/ha for lowland rice in recent times (Diagne & al., 2013).

4.3.1 Thresholds for weeds

In the TG-PPP publication from 1988 an overall threshold for weeds has been proposed that is based on soil coverage by weeds and set at 20 %. Taking into account that losses tend to be higher in low yielding environments than in agro-ecosystems with high yields (see section 4.1.3), the limits in table 11 might be a good guesstimate to start with for post-emergence herbicide treatment.

A first herbicide treatment before germination of rice is anyway required as otherwise there is a high risk of weeds to overgrow the rice seedlings.

Table 11: Proposed threshold limits for the second herbicide application in Nigeria*

Production system	Average yield (t/ha)	Threshold limit (% soil coverage by weeds)
Rainfed upland rice	1.44	15
Irrigated rice	2.24	20

*To be monitored permanently and amended from time to time if required.

So far, the correlation between weed incidence (e.g. % soil coverage) and yield loss has not yet been determined for the rice production conditions in Nigeria. Soil coverage by weeds can be determined by famers using a pictorial key (to be developed). This would be a nice topic for an MSc Thesis for one of the students in Kogi State University, for example.

Numbers provided by Matthes (2014) indicate that the cost for herbicide treatment is about ₦ 5200/ha and the rice price is ₦ 80000/t. In combination with yield data from Diagne & al. (2013) the value of the crop from one hectare is as indicated below:

- P_r = price of crop in rainfed upland rice (1,44 t at ₦ 80000/t: ₦ 115200)
- P_i = price of crop in irrigated rice (2.24 t at ₦ 80000/t: ₦ 179200)

Thus the cost of treatment of ₦ 5200/ha corresponds to 4.5 % of the entire yield/ha in rainfed upland rice and 2.9 % in irrigated rice indicating that losses above this range would justify herbicide treatment. As already mentioned in section 4.1.1, rice yield losses due to weeds in Africa can achieve any level between 20 and 100 % and yield increase in West Africa using weed control measures are about 15 – 23 % so that timely herbicide application practically always pays off.

4.3.2 Thresholds for diseases

The picture obtained from the assignment indicated that diseases were generally not a major loss factor of rice farming in Nigeria. Blast was identified as the most important disease, followed by Rice Yellow Mottle Virus and bacterial blight. Availability of rice fungicides in the market (few products; mainly ones containing mancozeb as an active ingredient and sold in small sachets containing just

80 g of the commercial product for use in vegetable crops) and very low use reported by farmers confirmed the assessment of the participants of the two stakeholder forums on IPM. Currently, only generic fungicides from China are available in the market. New products from Syngenta are in the registration process and may be available soon, but there are not any prices fixed yet.

For rice blast and bacterial blight, 2.5 – 4 infected tillers have been proposed as threshold limits per sampling unit (1 hill in transplanted rice and 10 tillers in broadcast rice) by TG-PPP (1988). These values have been determined in Thailand in other ecologic and economic framework conditions than in Nigeria and require counterchecking. After completion of the registration of rice fungicides a cost calculation for treatment of diseases can be made and a preliminary action threshold can be proposed.

4.3.3 Thresholds for insect and vertebrate pests

Similar to the overall impression on disease, insect pests appeared to be of minor importance only. During the 2nd stakeholder forum on IPM, stem borers incidence was reported not to exceed 2 – 5 % of infested tillers as a rule while all other insect pests were considered as occasional pests that cause only limited damage.

Heinrichs & Barrion (2004) reported gall midge loss trials performed by Williams (1997) in Nigeria. In on-farm trials, yield losses were between 2.3 and 3.1 % per 1 % increase in tillers with galls at 63 days after transplanting. Thus, one gall per five tillers at 49 – 63 days after transplanting was equivalent to 40 and 60 % yield losses, respectively. The TG-PPP (1988) recommendation for gall midge is 0.5 – 0.8 onion shoots per sampling unit (1 hill in transplanted rice and 10 tillers in broadcast rice). For stem borers, 0.5 – 1.5 dead hearts per sampling unit (corresponding to 5 – 15 %) have been proposed as threshold limits. The stem borer numbers reported from Nigeria are still below this level and control will only be required if the incidence increases.

Insecticide application cost per hectare indicated by Matthes (2014) is ₦ 1600. Cost for insecticides is about ₦ 2500/ha so that total cost involved is ₦ 4100.

The same crop values as in section 4.3.1 apply.

- P_r = price of crop in rainfed upland rice (1.44 t at ₦ 80000/t: ₦ 115200)
- P_i = price of crop in irrigated rice (2.24 t at ₦ 80000/t: ₦ 179200)

The cost of treatment of ₦ 4100/ha corresponds to 3.6 % of the yield/ha in rainfed upland rice and 2.3 % in irrigated rice. Losses above this range (which do not seem to be very probable) would justify insecticide treatment.

Posamentier (1989) described simulation experiments to determine yield loss due to tillers cut by rats (see table 12 on the next page).

These numbers can serve as an orientation for determining threshold limits based on cut tillers as direct observation of population size of field rodents is difficult. However, it should be taken into consideration that rodents reportedly only cause problems in rainfed rice cultivation systems in Nigeria and that their distribution in the field is far from being uniform. Direct observation and trapping as proposed in section 8.1 is the most appropriate solution for rodent under the current rice production conditions in Nigeria.

Table 12: % yield loss as compared to % tillers cut

Cultivation system	Growth stage	% damage	% yield loss
Transplanted rice	Tillering	10	2.7 increase
		25	3.2
		50	8.2
	Booting	10	10.4
		25	25.4
		50	37.8
	Mature	10	21.2
		25	30.6
		50	54.4
Deepwater rice	Tillering	10	9.1
		20	12.9
		40	14.6
	Booting	10	26.3
		20	32.9
		40	39.5
	Mature	10	28.8
		20	38.7
		40	58.7

Quelea weaver birds appear all of a sudden in Niger and Kogi States during their migrations from the North in huge numbers. Swarms contain thousands of individuals at least that invade the fields early in the morning and cause enormous losses in no time. This is a classical situation where the concept of threshold limits would make no sense and preventive measures as described in sections are required.

4.3.4 Conclusion on threshold limits for Nigeria

The biggest pest management challenges in rice production Nigeria today are weeds, birds and rodents where an economic threshold is not easy to establish (weeds) or even useless (quelea birds). Recommended prevention and integrated control strategies have been described in different chapters of this report (Chapters 3, 4 and 8).

As far as weeds, diseases and insect pests are concerned it is recommended that MSc or PhS students undertake systematic studies on incidence and losses that can serve as a basis for reviewing recommendations on threshold levels.

5 Main risks of indiscriminate intensification of pesticide use

With regard to the limited availability of suitable arable land practically everywhere in the world, it is hard to imagine that substantial increase in yields and farmers' incomes can be achieved without targeted use of appropriate pesticides within a sound IPM concept. This topic has been in the focus of much discussion or even polemic (see, for example, Avery, 2000).

Indiscriminate intensification of pesticide use, however, involves a number of serious hazards that can be grouped in four categories:

- Hazards for pesticide applicators

- Hazards for consumers
- Environmental hazards
- Resistance of target pests

These hazards are dealt with in more detail in sections below.

Rice is one of the world's crops with a high risk of losses caused by biological agents (see also section 4.1). This is why treatment with pesticides is widespread (according to Römbke & Moltmann, 1996, 9.6 % of the world crop protection market in 1990 was rice pesticides being the second place after cereals). At the same time, rice growing is one of the most problematic areas of pesticide application in developing countries. These are the major reasons why risk mitigation measures are of particular importance in this crop.

5.1 Occupational safety hazards

Rice farmers are the first ones who are exposed to hazards when they are treating their crop with pesticides. Depending on the active ingredient of the product, its formulation, its mode of application, and the protective measures applied by the farmer, the following hazards may apply:

- Acute intoxication by uptake via inhalation, through the skin (dermal) or by accidental swallowing
- Skin irritation or even chemical burn of the skin
- Sensitization, allergic potential, immunotoxicity
- Neurotoxicity
- Hormonal and endocrine-disrupting effects
- Chronic toxicity, carcinogenic and mutagenic action, and reproductive toxicity.

Cases studies on pesticide intoxication of West African smallholders have been described by Williamson (2011). She points out that African studies on pesticide impacts on health frequently highlight poor pesticide practice. Estimates of occupational poisoning and fatalities differ widely, however, because many cases have not been formally documented in health surveillance statistics. *“Little is known about the actual incidence and scale of poisonings”*. Surveying conducted by PAN Africa revealed that only 2 % of human poisoning incidents in Benin were reported seeking medical attention. All other cases did not enter official medical records. An overview of cases reported and pesticides involved is provided in the next section, because no clear distinction has been made between occupational and other farm household level intoxications.

Avery (2000) quoted IRRF findings saying that half of the African farmers using WHO danger category I (LD₅₀ oral < 5 mg/kg body weight) and II (LD₅₀ oral between 5 and 50 mg/kg body weight) pesticides during 15 to 25 years three times a year suffered from chronic eye problems. Skin, respiratory and respiratory problems have been recorded, too. Polyneuropathy probability increased from 0.02 % (non-users of pesticides) to 0.24 % (users). Avery (2000) attributed increased occupational hazards of farmers in developing countries to the following factors:

- Use of more dangerous pesticides than in developed countries
- Lack of respect of labels due to illiteracy or purchase of refilled pesticide without appropriate label
- Tendency towards more frequent use of pesticides
- Higher exposure due to less effective protective measures
- Highly hazardous mixing procedures usually in containers such as old oil drums

- Close contact to the spraying mixture during application, in most cases walking through the field using a knapsack sprayer spraying out in front of the farmer's path

Health hazards encountered in the field in Nigeria are mainly due to the factors listed below:

- Lack of information on pesticides other than product labels
- Insufficient labelling in some cases
- Lack of extension staff in the field (depending on the locality)
- Use of leaky sprayers
- Spraying technique (while walking forward) leading to high pesticide exposure
- Application in clothes that do not cover the entire body (Annex 4; photos 5064 – 5066)
- Inadequate protective equipment used
- Unavailability of protective equipment in rural areas
- High cost of protective equipment
- Misuse of products (in particular aluminium phosphide tablets)

Cases of reported pesticide intoxication seem to be rare in Nigeria. One farmer in Wushishi interviewed during the mission remembered a case of sickness and vomiting after 2,4-D application and skin irritation with peeling off when using leaky sprayers. However, this information cannot be taken as an indicator as the dark figure is probably very high.

Many people (farmers, extension workers, scientists, pesticide dealers ADP staff members and others) confirmed during the mission that farmers are regularly trained on safe pesticide use. In several locations it was reported that farmers consult extensionists when they do not understand pesticide labels or are not familiar with the products that they bought. Obviously they have sufficient theoretical knowledge but use of appropriate protective equipment is definitely rare. In Lokoja, farmers reported that women tend to use brooms for pesticide application instead of sprayers which results in pesticide waste and increased intoxication hazards.

Risk mitigation measures have been described, amongst others, in a concise way using simple language and clear pictures in CropLife International guidelines, posters and extension material (see section 9.4) and extension material from ProAgri in Benin Republic, for example. For every pesticide (commercial product) recommended by and applied within the framework of CARI, the material safety data sheet (MSDS) should be obtained from the pesticide dealer and relevant information from the MSDS (e.g. appropriate safety precautions, first aid, disposal, etc.) should be included in the agricultural training and extension materials of CARI.

5.2 Excess of food thresholds and associated consumer risks

While there is not much information on excess of threshold limits in food such as ADI, ARfD or MRL because of lack of legislation and screening in African countries, there are reported cases from surveys: *“Contamination of food and re-use of empty containers for food and drink accounted for 57 % of all cases in Benin and 86 % of all fatal poisonings, showing how important this route is in putting families in danger”* (Williamson, 2011). On average, 16 % of the 619 incidents investigated in Benin were fatal. Two tables in this study provide overviews of numbers of cases in several countries and pesticides involved (occupational and domestic poisoning included). These tables are reproduced on the following page (tables 13 and 14).

Table 13: Summary of poisoning cases collected in West Africa, 1999 – 2009 by PAN Africa (from Williamson, 2011)

Country, Period, N° of cases	Male	Female	Adults	Children	Fatality rate
Benin, 1999 – 2000, n = 148	86 %	14 %	72 %	28 %	7 %
Benin, 2000 – 2001, n = 265	75 %	25 %	65 %	35 %	9 %
Benin, 2001 – 2002, n = 206	61 %	39 %	44 %	56 %	32 %
Senegal, 1999 – 2001, n = 84	67 %	33 %	68 %	32 %	23 %
Senegal, 2002 – 2009, n = 258	86 %*	4 %*	90 %**	5 %**	10 %
Mali, 2002 – 2009, n = 47	100 %	0 %	100 %	0 %	0 %

*10 %: gender not specified

**5 %: age not specified

Table 14: Active ingredients implicated in poisoning cases from table 12 (after Williamson, 2011)

Active ingredient(s) involved	Benin 1999 - 2000	Benin 2000 – 2001	Benin 2001 - 2002	Senegal 1999 - 2001	Senegal + Mali 2002 – 2009
Endosulfan	60 %	83 %	53 %	12 %	24 %
Methamidophos					21 %
Dimethoate					6 %
Dimethoate + cypermethrin	13 %		4.5 %	1 %	
Cypermethrin + profenfos					6 %
Cypermethrin + chlorpyrifos	6 %				
Chlorpyrifos		2 %	10 %		
λ-cyhalothrin + profenfos or cypermethrin	4 %	10 %	16.5 %		
Carbofuran + thiram + benomyl				6 %	
Diamine + propanil					6 %
Cypermethrin + acetamiprid + triazophos					6 %
Methamidophos + methomyl					4 %
Deltamethrin					3 %
Other named products	17 %	1.5 %	4.5 %	8 %	
Undetermined pesticides		3.5 %	11.5 %	73 %	24 %

Comment: % figures relate to total number of poisoning cases documented and not to % cases where a compound was implicated.

It is important to note that several pesticides used in rice cultivation in Nigeria show up in table 14 (cypermethrin, λ-cyhalothrin, benomyl, propanil). All these active ingredients are components of mixtures used in particular for seed coating. Because of the hazardous nature of these substances and their comparatively high concentration in pesticides for seed dressing, this job should be left to well-trained pesticide applicators and not be performed by farmers.

Comment: According to information provided by Dr. Osiname, there is also a risk of secondary intoxication of humans who eat insects (such as locusts and armyworm larvae) or birds that have been exposed to pesticides. Such insects or birds are collected either alive when they have already reduced vitality or are even dead.

The only way to protect consumers is training of farmers on proper use of appropriate pesticides (in particular right dosage and respect of waiting periods) and monitoring of pesticide residues. Training of farmers is taking place already and can easily be intensified. Monitoring of pesticide residues is not particularly systematic in Nigeria, but some information is available (e.g. by Anzene & al, 2014 on organochlorine pesticide residues) which provides enough reason to be worried about the current situation. The findings in this study do not necessarily indicate continuous use of banned substances but may rather be attributed to their long persistence in the soil and ground water. In order to avoid secondary intoxication by consumption of target organisms of plant protection measures awareness is required.

5.3 Environmental hazards

For the general public, hazards related to pesticides that come to mind in the first place are related to the natural environment. Broad awareness for this topic arose for the first time with the book "Silent Spring" by Rachel Carson that first appeared in 1962. Carson documented the detrimental effects of the indiscriminate use of pesticides on birds and on other aspects of the environment. Apart from pesticide use, careless pesticide disposal (including packages) and obsolete pesticide stocks constitute hazards.

Environmental hazard categories of pesticides include the ones listed below:

- Aquatic toxicity (toxicity for organisms living in the water, such as fish and aquatic invertebrates)
- Bird toxicity
- Bee toxicity (with negative impact on pollination)
- Earthworm toxicity (with side-effects on decomposition of organic matter in the soil)
- Persistence (poor degradation in the environment), and bioaccumulation (accumulation of substances in living organisms).

Römbke & Moltmann (1996) listed pesticide application mistakes that cause environmental hazards:

- Incorrect dosage
- Misuse
- Choice of wrong product
- Unfit spraying equipment
- Insufficient rinsing after use
- Wrong timing
- Drift and run-off

It is important to keep in mind that even when pesticides are properly applied a certain proportion may end up in surface or ground water or in the air. Up to 90 % of particularly volatile substances may evaporate.

Case studies of environmental hazards related to pesticide use in Africa are rare. Some studies on persistent obsolete substances such as chlorinated hydrocarbons (e.g. DDT) and on the impact of desert locust control have been undertaken in the past but these studies are not particularly relevant for current rice cultivation issues as active ingredients involved and conditions of use differ very much. Anyway, environmental issues related to pesticides tend to be very complex because many parameters influence the action of a substance in the natural environment. Römbke & Moltmann (1996) listed some classical examples of environmental effects caused by pesticides:

- Severe health damage to predatory birds due to bioaccumulation of chlorinated hydrocarbons such as DDT in the food chain*
- Large-scale dispersion of the herbicide atrazine through evaporation or leaching into the groundwater
- Absorption of paraquat to soil particles resulting in high persistence, but not necessarily bioavailability
- Accumulation of copper in topsoils of vineyards (by the way: copper preparations play an important role as fungicides in organic agriculture)
- Increase in numbers of previously negligible pests after insecticide application

*A more recent case is secondary intoxication of predators caused by second generation anticoagulant rodenticides that lead to severe restrictions in the use of these substances (risk mitigation measures) which are part of the product registration in EU member states (UBA, 2014).

In the CARI program context, the issue of associated aquafarming (raising *Tilapia*) is being discussed. If fish production is to be included in irrigated rice production use of pesticides has to be limited to products and circumstances of use that do not harm fish (cf. comments in tables 3, 5, 6, 8 and 15 of this study).

Risk mitigation measures have been described in many publications including CropLife International guidelines (see section 9.4) and will be dealt with in CARI training material for farmers, too.

5.4 Special hazards associated with rice pesticides in Nigeria

Substances that have been reported by CARI staff members and farmers to be used for treatment of rice have been checked for hazard features by the author of this study. Most of the information provided in table 15 on the next page has been taken from Greenpeace (2010). For description and evaluation of the substances in this table the following characteristics have been used:

- acute toxicity for applicators and consumers
- chronic toxicity
- carcinogenic effect
- mutagenic effect (damaging to genes)
- reproductive toxicity
- immunotoxicity
- neurotoxicity
- hormonal and endocrine-disrupting effects
- aquatic toxicity (toxicity for organisms living in the water)
- bird toxicity
- bee toxicity
- earthworm toxicity
- persistence (degradation in the environment), and
- bioaccumulation (accumulation of substances in organisms).

Out of the hazard ranking provided by Greenpeace from 0 – 5 for all these categories (0 = practically not..., 1 = very low..., 2 = low..., 3 = moderate..., 4 = high..., and 5 = very high...), only 4 (high) and 5 (very high hazards) have been included in table 15.

Table 15: Pesticides used by rice farmers in Nigeria and related hazards (Main sources of information on hazards used: GESTIS database and Greenpeace, 2010)

Active ingredient	Used by CARI farmers	Hazards to human health	Hazards to the environment	Other hazards	Conclusion and comments
2,4-D	No	reproductive toxicity; neurotoxic; associated with Parkinson's disease	very high aquatic toxicity with long lasting effects	-	Considered to be a highly hazardous substance; not to be recommended
Benomyl	Yes	reproductive toxicity; mutagenic	very high aquatic toxicity	-	Considered to be a highly hazardous substance; residues frequently encountered in food; not to be recommended
Bentazone	Yes	high immunotoxicity	-	high persistence	In the EU classified as hazardous for aquatic environments; use with special care in rice production
Carbofuran	No	very low ARfD; high acute toxicity; neurotoxic	very high aquatic toxicity; very toxic for birds and bees	-	Obsolete and highly hazardous substance which should be banned in Nigeria
Cypermethrin/ λ-cyhalothrin/ benomyl	Yes	low ARfD; neurotoxic/ low ARfD; high acute toxicity; neurotoxic reproductive toxicity; mutagenic	very high aquatic toxicity; very toxic for bees/ very high aquatic toxicity; very toxic for bees/ very high aquatic toxicity	bioaccumulative bioaccumulative; endocrine-disrupting effects	A very hazardous mixture in terms of human and environmental health; further use should be discontinued
Dichlorvos (DDVP)	No	low ARfD; high acute toxicity; neurotoxic	very high aquatic toxicity; very toxic for birds and bees	-	Highly hazardous substance that should not be used on harvested rice
Glyphosate	Yes	-	high aquatic toxicity	high persistence	Glyphosate application requires precautions to avoid water pollution
Isazofos	No	high toxicity when inhaled	very high aquatic toxicity (also long-term effects)	no reliable information found	Take precautions to avoid water pollution
Mancozeb	Yes	carcinogenic; reproductive toxicity; neurotoxic; associated with Parkinson's disease	-	endocrine-disrupting effects	Residues frequently encountered in food; problematic substance to be replaced by less hazardous fungicides
Paraquat	No	low ARfD; very high dermal toxicity; neurotoxic; associated with Parkinson's disease	high aquatic toxicity	high persistence	Not recommended because of high human health hazards
Phosphine	No	very high acute toxicity	high aquatic toxicity	-	Because of special requirements in terms of application and safety only to be used by trained specialists
Propanil	Yes	Low ADI; carcinogenic;	very high aquatic toxicity; toxic for birds	endocrine-disrupting effects	Substance to be used with care to avoid adverse environmental effects in particular

Colour code:	Pesticide that requires special precautions for use	Pesticide that should not be used any longer
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Special hazards associated with pesticides in Nigeria can be summarized as follows:

- Registration and broad availability of many obsolete substances with high human health and environmental hazards
- Most products are generics from China that have not been tested for conformity (chemical composition, concentration, etc.)
- Storage under hot conditions that may lead to (at least partly) decomposition before the indicated end of shelf life
- Lack of advice to farmers for safe and proper pesticide use
- Inadequate safety measures and protective equipment during application of pesticides
- Dumping of empty pesticide containers, mostly in the field, but also close to farmers' homes and in one case (Lokoja) in huge numbers (Annex 4; photos 5088, 5090, 5132 – 5135, 5143, 5144, 5146, 5162, 5163)

A particular hazard of serious intoxication with potentially mortal outcome can arise when rice is stored in living rooms as seen in Abejukolo (Annex 4; photos 5282 - 5285) and treated with aluminium phosphide tablets.

5.5 Target organism resistance hazard

Resistances of target organisms such as weeds, disease agents and pests are the result of selection of tolerant strains exposed to a certain active ingredient over generations. Tolerant or resistant individuals cannot be killed by dosages that would kill the majority of susceptible populations. There are basically two different mechanisms of resistance which involve either the detoxification of the active ingredient in the target organism's metabolism or a tolerance due to a decreased sensitivity to the presence of the toxic substance at its site of action (Dent, 1991). In insects and rodents, also a behavioral avoidance of the substance involved has been observed.

Resistances of target organisms are known since many decades. Dent (1991) gave a brief account and mentioned that citrus scales in California developed hydrogen cyanide tolerance as early as 1911. Resistances became a common concern in the late 1940s when organochlorine insecticides such as dieldrin were widely used. Since then, resistances against pesticides have become a widespread phenomenon involving many active ingredients. Table 3 in section 3.1 shows, for example, that different weed species have developed resistance against 50 % (8/16) of the common rice herbicides listed by Rodenburg & Johnson (2013). The IRAC Arthropod Pesticide Resistance Database hosted at Michigan State University gives an overview of pesticide resistance in insects.

Phosphine resistance in stored product insects is an important issue, too, that has been reported in many publications. Nayak (2012) has given a recent account. Phosphine resistance had been surveyed extensively by FAO for the first time in 1976 and was found at that time in 33 out of 82 countries. *"...the situation has worsened during the last two decades in terms of both frequency and strength of resistance. (...) In most of the cases, the development of resistance is presumed to be related to inadequate fumigation practices involving poorly sealed structures and repeated fumigations."* (Nayak, 2012). It is important to know that small-scale rice farmers do not have the knowledge and the material required to carry out rice fumigation without particular hazard of development of rice pest resistance against phosphine.

Dent (1991) refers to four ways in which pesticide resistance can be managed:

1. Manipulation of insect population dynamics

This is actually difficult to achieve in practice because economic injury levels tend to be

below the pest population size effectively limited by density dependent processes such as intraspecific competition and predation.

2. Influence of refuges and dispersal

The presence of untreated areas may lead to dispersal of resistant individuals from the treated area and inflow of susceptible ones resulting in dilution of resistance genes. In extensive agricultural systems (upland rice cultivation) there are better preconditions for this type of resistance management than in intensive ones where monoculture is practiced (irrigated rice production).

3. Dosage rates

Prevention of resistance includes using high enough dosages to kill all individuals of the target organism. While it is feasible to control factors like dosage calculation, application techniques, etc. to a satisfactory degree, for economic and environmental reasons it is excluded to apply dosages that would definitely kill all individuals including the ones with a naturally higher pesticide tolerance.

4. Use of a number of pesticides

If pesticides with different active ingredients are used in rotation the chance of development of resistance is minimized. For treatment of rice there are sufficient suitable active ingredients and formulations on the market to follow this approach.

A sound IPM strategy is required in the CARI program that is designed to prevent the development of resistance. Efficient management measures include:

- Use of tolerant varieties
- Agronomic preventive measures
- Pesticide treatment only when required (application of action thresholds)
- Rotation of active ingredients

As pesticides are essential elements in a sound rice IPM concept leading to higher yields and increased incomes appropriate resistance management is indispensable.

6 Assessment of existing regulations and mechanisms for trade, sale, use and disposal of pesticides (formal and informal)

An important recent source on practically all issues related to pesticides in Nigeria is the baseline study on pesticide use by Emechebe & al. (2013). While there is obviously no comprehensive national pesticide regulation in Nigeria, Pesticide Registration Regulations have been put into force in 2005 under the Drugs and Related Products Act from 1996 (as amended). The National Agency for Food and Drug Administration and Control (NAFDAC) is responsible for pesticides registration while the National Environmental Standards and Regulation Enforcement Agency (NESREA) *“is actively involved in ensuring safe use and management of pesticides”* (Emechebe & al., 2013). The National Cereals Research Institute (NCRI) in Bida, Niger State, has the mandate to conduct research into the genetic improvement of rice and other crops (not only cereals as the name would indicate) as well as overall farming systems and resource management, research and extension. During a visit to the institute the director, Dr. S Agboire, affirmed that testing of pesticides for registration purposes is also part of the institute’s mandate. However, many products seem to be registered by NAFDAC without any testing. The information obtained from NCRI staff members was of a very general nature and it is difficult to conclude which are the merits of the research conducted in the institute. Dr. Agboire emphasized that the approach of the institute is a holistic one and that they try to avoid pesticides. NCRI organizes monthly meetings with ADP research agents. Written information (research reports, etc.) was not provided. The director made it clear that the institute is lacking funds for research.

There seem to be no particular quality standards for pesticides and no quality control with regards to conformity, formulation, etc. The MSc thesis of Shaibu (2011) also includes some information on regulation. He lists the following texts without providing any further details on their contents:

- FEPA Decree 58 of 1988 as amended by Decree 59 of 1992 and 1999 dealing with disposal and distribution of pesticides
- NAFDAC Decree 15 of 1993, as amended by decree 19 of 1999
- The Factories Act 1990 being implemented by the Factories Inspectorate Division of FMLP
- The Harmful Waste (Special Criminal Provisions etc.) Decree 42 of 1988 being implemented by FMEV.

A consistent pesticide policy seems to be lacking, but Shaibu (2011) refers to an agricultural policy from 1988 that includes two general pest control objectives:

1. "Control, and/or eradicate and maintain good surveillance of the major economic pests whose outbreaks are responsible for large-scale damage/loss in agricultural production."
2. "Provide protection to man and animals against vectors of deadly diseases."

There is no indication, however, whether this policy includes aspects of IPM, hazards related to pesticide handling and application, occupational, consumer and environmental hazards, etc.

NESREA has published a list with 26 pesticides that have been banned in Nigeria (table 31 of the study by Emechebe & al., 2013) and 11 restricted ones (table 32 in the same publication). Shaibu (2011) lists 14 banned compounds. It is important to know that formulations containing 7 % or more benomyl + 10 % or more carbofuran + 15 % or more thiram have been banned. Such or similar mixtures had been recommended in former extension brochures (e.g. Nwilene & al., no year and Oikeh & al., no year). Substances regulated within the framework of the Rotterdam and Stockholm Conventions (PIC and POP chemicals) have been completely banned in Nigeria. There are rumors that a more or less complete list of more than 500 pesticides registered by NAFDAC exists but all efforts to obtain it (e.g. official request and subsequent visit to NAFDAC) were in vain. During the stakeholder forum it became quickly evident from the discussions that mandates partially overlap and that responsibilities are not always well defined. First-hand knowledge on pesticide registration (e.g. current lists of registered and banned products) is not easily available.

A number of Federal and State ministries, departments and agencies including ADPs (Agricultural Development Projects) are in charge of advising farmers on pesticide use. They often lack resources to provide adequate extension services. Partly, as it is the case with the Produce and Pest Control unit of the Ministry of Agriculture in Niger State, they give problematic recommendations, e.g. on aluminium phosphide use as a post-harvest protectant or atrazine* and paraquat application against weeds.

*Atrazine is characterized by very high toxicity for aquatic organisms, persistence, bioaccumulation and endocrine disruption and not registered in the EU. Not recommended in particular because of its environmental hazards.

7 Assessment of the pesticide market in Nigeria

Recent and comprehensive information on pesticides registered, traded and used in Nigeria has been provided by Emechebe & al. (2013). They mention more than 500 pesticides registered in the country by NAFDAC. According to their study, 98 % of the marketed pesticides are registered. Amongst these products there are 3 organochlorine insecticides (including lindane for restricted use in cocoa), 7

carbamates, a vast range of organophosphorous compounds and others including 8 synthetic pyrethroids. This is certainly not a product range reflecting the state of the art of pesticide use in current IPM schemes. Shaibu (2011) lists 79 compounds (34 insecticides and 45 herbicides + fungicides) in his study that is focused on rice.

According to survey results of Emechebe & al. (2013) farmers purchase their pesticides mainly from the open market (about 74 %). The majority of them (78 %) reads and follows instructions given on the label. As far as repackaged pesticides are concerned, two thirds come with full labels while on one third of the products the label is incomplete. The consultant's own observations during the assignment showed, however, that recommendations concerning protective clothes and equipment are known by farmers but hardly ever followed. Farmers said that protective equipment is too expensive. Farmers said that they washed their clothes after pesticide application and before going home.

As it has been mentioned before, the vast majority of the pesticides are generics, mainly from China that are commercialized with limited support in terms of proper use and safety. The range of active ingredients found in the market largely reflected what was observed by Emechebe & al. (2013) and Shaibu (2011).

The consultant visited one pesticide importer for SARO brand generics from China in Suleja (Niger State) and a couple of smaller and bigger distributors and retailers in different places of Kogi and Niger State (Suleja, Bida and Ayingba). The wholesale and retail company Jetan Agro Solutions Limited, a CARI cooperation partner from Bida was amongst the companies visited. In addition, discussions took place with the Syngenta Nigeria representative, Mr. I Itoandon.

In bigger stores the range of commercial products was partially quite broad but it was striking that the range of active ingredients was pretty much limited. Most rice herbicides contained glyphosate, 2,4-D amine, paraquat or propanil. Herbicides are generally sold in bottles containing 1 l of commercial product. Insecticides, also sold in 1 l bottles, consisted generally of cypermethrine, λ -cyhalothrine for use in the field or DDVP for post-harvest use mainly. Fumigants formulated as aluminium phosphide pellets come in metal containers with varying contents of about 1 – 1.5 kg. Inside these containers there are smaller tubes that are sold per piece. Some dealers even sell individual pellets or tablets that start decomposing and releasing the extremely toxic phosphine gas soon after opening of the tube and while the buyer transports them home. The prevailing fungicide was mancozeb, generally sold in sachets of 80 g that are meant to treat vegetables in the first place. There are also mixtures of fungicides and insecticides for seed dressing in the market which are bought by farmers for seed treatment.

Prices varied to some extent from place to place. Generic herbicides are available from about ₦ 750/l on. Generic glyphosate products start at less than 1.000 ₦/l (e.g. ₦ 800 - 900) while a comparable Syngenta product (Touchdown) or Roundup by Monsanto costs around 1.500 ₦/l, but prices of up to ₦ 1900/l were reported, too. Generic insecticides are in a similar range (about ₦ 800/l for cypermethrine formulations, ₦ 1000/l for λ -cyhalothrine and ₦ 1050/l for DDVP products). Mancozeb bags containing 80 g of the product cost about ₦ 130. The price of 960 g tin of aluminium phosphide is about 4000 ₦; one tube containing 10 tablets is sold for ₦ 300.

Sales of other products than pesticides took place to a limited scale. Jetan sells sprayers, protective masks (dust masks in fact) and seed including dressed rice seeds. Some of the other dealers sell sprayers, masks, gloves and, in one case, boots. Prices of safety equipment are about ₦ 200 for simple dust masks, ₦ 300 – 400 for a pair of rubber gloves, and ₦ 2500 for a pair of rubber boots. Jetan also organizes customer safety demonstrations.

Farmers tend to purchase generics preferably because of the price in the first place. The range of products available also includes very toxic ones such as fumigants that are freely available to everyone and should not be used by untrained people (Annex 4; photos 4946 – 4954, 5077). The quality (effectiveness) of products changes which is probably due to different factors (e.g. formulation, storage and display under hot conditions, etc.). Interviewed farmers stated that they store the pesticides after purchase in a separate locked room away from the house.

There is no need to obtain a particular license for selling pesticides. It is sufficient to register a trade enterprise. Some of the dealers belong to the Association of Agrochemical Dealers of Nigeria but membership is not compulsory. Apparently the association is not very dynamic in terms of promoting effective and safe use of pesticides or providing any other support to their members and/or customers.

8 IPM strategy and assessment of relevance (cost-effectiveness) of recommendations in the framework of the CARI program

8.1 Proposal for a CARI rice IPM strategy

The principles outlined on pages 5 to 8 of the Integrated Pest Management Extension Guide n° 2 published by Youdeowei (2002) appear appropriate as a guidance to CARI rice farmers, too. Many of these principles have also been written down in the book of Onwueme & Sinha (1991). In this chapter, the author basically follows this approach and completes the IPM strategy with elements from AfricaRice research and publications and proposals for threshold limits based on the TG-PPP Rice Pest Surveillance Manual (1988) and own investigations in Nigeria.

In table 16 an IPM strategy is proposed for the CARI program which has been broken down in recommendations for practices and working steps (here called “components”) that complement each other. These components can easily be transferred in pictures with explanatory notes similar to the ones in the picture blocks of ProAgri (no year) from Benin Republic developed for cotton farmers. The components are basically the same for lowland and upland rice production but details of implementation may differ considerably. In this case a distinction between the two cropping systems has been made under the heading “How?” In Niger State, two lowland rice cropping systems occur: rained and irrigated cultivation. Upland rice cultivation is practiced in Kogi and Niger States.

Table 16: Proposals for an IPM strategy in Nigeria

Component 1: Choose a suitable planting site with fertile soil	
<p>Why? It goes without saying that a suitable site with fertile soil will result in strong and healthy rice plants while suboptimum conditions stress and weaken the plants and make them more susceptible to weed competition and attack by diseases and pests.</p>	<p>How? Lowland rice: Fertile soils with good water retention capacity (soils containing clay and organic matter, i.e. loamy soil) are most suitable for cultivation. Generally, heavy valley soils are appropriate. Upland rice: Fertile land with good drainage and good water retention capacity is required. Only grow rice in zones with at least 14 - 20 mm of five-day rainfall during the vegetation cycle. Always obtain advice from a soil-testing unit if you want to grow rice for several years on the same piece of land.</p>

Component 2: Prepare the field properly	
<p>Why? For irrigated lowland rice proper levelling of the planting site is a precondition for uniform irrigation and control of weeds. If irrigation water does not cover the field completely some weeds may grow up faster than the rice plants and suppress them.</p> <p>Rainfed rice fields should be cleared from all remnants of shrubs, etc. to facilitate sowing, weeding and other work.</p>	<p>How? Lowland rice: Level the ground properly to facilitate uniform flooding and prevent weed infestation. In areas with many perennial weeds (e.g. sedges), disc-plough the field immediately after harvest in November/December to expose the weed roots to the sun.</p> <p>Upland rice: Remove stumps, roots, etc. from newly cleared land. Plow and two weeks later disc harrow to kill weeds. Incomplete land clearing, broadcasting of seed and intercropping with other crops such as cassava or yams in irregular patterns will result in low yields. Crop rotation or intercropping in rows is preferable as crops can be better managed (weeding will be much easier).</p>
Component 3: Plant tolerant rice varieties and use healthy seeds	
<p>Why? Planting of tolerant rice varieties and sowing of healthy seeds decreases weed, disease and pest incidence independent of any other phytosanitary measures.</p>	<p>How? Use vigorously tillering rice varieties that are able to compete with weeds. Disease resistant varieties help to increase yield and minimize pesticide use at the same time. In AfRGM affected regions early maturing varieties can be advantageous, e.g. Cisdane.</p> <p>Use dressed seed from reliable sources that have been treated with a suitable mixture of pesticides against common insect pests and diseases.</p> <p>Recommended rice varieties: see section 6.2!</p>
Component 4: Plant rice in rows at the right distance	
<p>Why? Weed control in broadcasted rice is difficult and can only be done using many hours of manual work. This leads to an increased workload, in particular for women and children. Rice sown or planted in rows facilitates mechanical weed control with appropriate equipment.</p>	<p>How? Lowland rice: A distance of 20 cm between rows is recommended in combination with mechanical weeding.</p> <p>Upland rice: Row-seeding with inter-row spaces of 30 – 40 cm is recommended. Under these conditions, mechanical weeding equipment can be used.</p> <p>Mechanical equipment may be purchased by a group of farmers (e.g. a cooperative) or a service company (if available) can do the job.</p>
Component 5: Plant rice at the appropriate time	
<p>Why? Every crop has its favourable planting time in terms of water availability (rainfall), temperatures and other factors important for the crop. Planting at the right time facilitates full and healthy crop development while planting at the wrong time will result in stress for the plants which weakens them and makes them more susceptible for weed, disease and pest attack.</p>	<p>How? For each cropping system (upland or lowland rice, irrigated or rainfed) and every rice growing region appropriate sowing and transplanting periods have been identified. Respect these recommendations but make smart use of margins that you have. Early wet season rice, for example, may escape damage caused by the AfRGM while late planting may result in heavy damage. Synchronized planting over a large area helps the most susceptible stage of rice to escape from AfRGM damage.</p> <p>Other diseases and pests may also cause less damage if rice is planted as early as possible because they generally have life cycles that are adapted to major crop growing periods.</p>
Component 6: Weed early enough and repeat weeding at the right time	
<p>Why? If weeding is done too late or not often enough the rice plant falls behind the weeds in terms of size and vigour and will not produce a good yield.</p>	<p>How? In direct sown lowland rice, first weeding should be done about 15 days after emergence; in transplanted rice 14 to 20 days after transplanting and again 30 to 40 days after transplanting.</p> <p>In upland rice, first weeding is recommended within 2 to 3 weeks after emergence (the earlier weeding is done the better). Second weeding should be done 6 to 7 weeks after emergence, before panicle initiation and second N topdressing, to minimize the effect of the weeding process on panicle initiation. If necessary, weed a third time.</p> <p>If herbicides are used, other recommendations apply (e.g. pre-emergence herbicides have to be applied not later than 24 hours after sowing).</p> <p>Weed-free fields may have less AfRGM infestation than others.</p>
Component 7: Practice good soil management and fertilization	
<p>Why? The soil provides practically all nutrients that a plant requires. Well-nourished crops have a higher vitality than poorly nourished ones and are less susceptible to weed, disease and pest attack.</p>	<p>How? Always follow recommendations for fertilizer application. Do not use more than recommended. High N, for example, is favourable for rice blast infestation. Don't apply more than 35 kg of N fertilizer per ha at a single dose.</p> <p>Deep-plowing followed by submergence helps to control stem borers.</p>

Component 8: Practice good water/irrigation management	
Why? Water is one of the most essential factors for all plants to grow (and in particular rice) and water stress will reduce the crop's capacity to cope with weeds, diseases and pests.	How? Upland and other rainfed rice is entirely depending on rainfall. In this cropping system cultivation at the right time (see component 5) as well as proper choice and preparation (constructing bunds and leveling) of the field to retain the water provided by rainfalls (cf. components 1 and 2) are essential to make best use of the available water. In dryer areas plant drought-resistant rice varieties. Flood fields for irrigated rice 2 weeks before final preparations for planting to kill weeds.
Component 9: Monitor rice fields regularly	
Why? IPM relies on informed decisions concerning crop development, incidence of weeds, diseases and pests and other factors. Close monitoring of the fields is the only ways to obtain the information required to decide on a pesticide treatment, for example, or other pest management measures.	How? Visit your rice field as often and as regularly as possible, at least once a week. Look for weed emergence, typical damage caused by diseases and pests and pests in all their life stages. Use monitoring techniques recommended by the CARI program) and keep records of all observations. If weeds, pests or signs of damage reach a threshold limit, take appropriate action.
Component 10: Practice proper sanitation	
Why? Diseases and pests may have reservoirs in and around fields that facilitate their survival and dispersal. Such reservoirs include harvest remnants such as straw or alternative host plants for diseases or pests which should be removed and destroyed.	How? Remove or destroy all remnants from harvest as soon as possible so that there are no hosts for diseases and pests left. Uproot perennial weeds and let them dry out. Eliminate host plants of pests and diseases (e.g. wild rice – host of AfRGM) close to rice fields, especially during the dry season. Don't mulch rainfed rice fields where there is a risk of termite attack.
Component 11: Apply the right pesticides at the right time	
Why? All pesticides have a certain action that is different for different target species and their life stages. Pesticides that are applied too early are a waste because there may not be enough agents causing damage to justify a treatment from the economic point of view. A treatment that is done too late is also a waste because losses may have occurred already that are higher than the benefit obtained from the treatment.	How? Buy recommended pesticides only from authorized and reliable dealers. If you have any doubts whether a pesticide is okay follow CARI advice. Apply appropriate pesticides (see section 6.3) according to the respective threshold limit (see section 4.3). In direct-seeded lowland rice , rice and weeds germinate at about the same time and there is no standing water to inhibit weed growth → use a pre-emergence herbicide! Change active ingredient if you repeat a treatment to prevent development of resistance in the target organism. Recommended rice pesticides: see section 6.3!
Component 12: Support natural enemies of weeds and pests	
Why? Natural enemies of weeds or pests support the farmer in his fight against enemies of his crops without additional cost. This is why it is wise to protect them against poisoning and other damage.	How? The best way of protecting natural enemies of rice weeds (mainly herbivorous insects) or pests (predators and parasitoids) is to use insecticides with care because they would often harm the beneficial insects more than the pests. Spray insecticides only when it is required and observe all specifications of the label. Time insecticide application properly.
Component 13: Protect your rice crop efficiently against Quelea birds and rodents	
Why? Quelea birds come overnight in big swarms and cause big damage in short time if the crop is not sufficiently protected. Field rats can be a serious problem in rainfed rice while placing poisonous bait is a hazard for other animals which do not harm the crop.	How? Scaring of birds is tedious and not efficient. Covering the rice crop with fishing nets from the moment of panicle appearance is a good option to keep off birds for fields that are not to big (up to around 1 ha). By the way: Effective weed control reduces quelea incidence because these birds prefer small grass seeds to rice kernels and are attracted to sites where they find their preferred food. Planting of maize around rice fields as a trap crop can also contribute to limit rice losses due to birds. There are two methods available to catch field rats without hazards to the environment: Placing snap traps on their way (control every day, remove dead rats and charge the trap again). Use of stripes of fishing nets where the rats get entangled has also proven to be efficiently.

Component 14: Apply good harvesting methods	
Why? Rice grain that is harvested too early is not ripe enough to be properly stored. Late harvest may lead to increased loss by shattering of grain. Inappropriate harvesting methods can mechanically damage the grains that become susceptible to mould and stored product insect attack.	How? Harvest the rice when the grains have become hard and the colour has turned yellowish brown (about 30 – 45 days after flowering). Thresh only after proper drying (5 – 10 days; the moisture content should be 12 – 13 % maximum) to avoid damage to the grains. Thresh carefully to avoid dehusking and breaking of grains. Winnowing separates all residues including broken grain from the harvested rice. Broken grain is much more easily attacked by stored product insect pests and mould.
Component 15: Use appropriate and clean storage facilities	
Why? Rain and rodents can easily penetrate structures that are not well designed. Insects can easily survive in remnants from harvest for months and infest new produce.	How? Construct rain- and rodent-proof storage structures. A solid water-tight roof is essential and a raised platform with metal rodent sheets keeps rats and mice away. Clean storage facilities thoroughly before storing the new harvest. In particular, remove all old grains as they may be attacked by stored product insects. Use the PICS triple bag for paddy storage.
Component 16: Practice crop rotation	
Why? Crop rotation may break a disease's or pest's life cycle because of lack of its host necessary for survival.	How? Fields where crops with different pests and diseases from the ones that occur on rice have been grown before (e.g. groundnut, cowpea, soy beans, cassava, yam or vegetable crops) are particularly suitable.
Component 17: Seek good advice if you have any problem	
Why? Nobody knows everything. A new problem may arise at any moment. But there may be a person that can advise you.	How? Depending on the problem, address to agricultural extension agents, CARI staff members, authorized pesticide dealers or other persons that may be able to help you. If they do not know the solution they generally know where to get advice. Attend training sessions and ask for written information such as leaflets and brochures.
Component 18: Refrain from dubious practices	
Why? Some pesticide application practices may result in severe damage to the crop, to human health or to the natural environment.	How? Pesticides for seed dressing or coating have high contents of active ingredients and are generally more hazardous than most pesticides for application in the field. This is why this job should be done by people who received special instruction and who have proper safety equipment. Seed dressing should not be done by untrained farmers! Dressed seed of good quality is available in the market. Always observe the rules of proper pesticide handling: <ul style="list-style-type: none"> • Only buy pesticide quantities that you will need during one cropping season. Otherwise stocks may become obsolete and lose their effect. • Don't refill pesticides in other bottles or cans to prevent accidents. • Lock pesticides safely away from children and other persons who are not trained to use them. • Don't dump pesticide containers close to the field or home. Destroy them and bury them in the ground far from any wells, ponds and streams. • Don't use empty pesticide containers for any other purpose such as ablution at the mosque because of the intoxication hazard. • Never use products of uncertain origin or quality! No fumigant (aluminium phosphide) application by farmers! This treatment should only be done in places where qualified applicators and the proper equipment are available. Use snap traps instead of aluminium phosphide tablets against rodents in the store.

Upland rice is grown under rainfed conditions and characterized by low yields. This is why IPM recommendations for upland rice should be focused on cropping methods that result in healthy rice plants which lead to less weed, disease and pest attack and, as a consequence, increased yields. Some of the above recommendations that require substantial input in terms of money may not be feasible for the moment for upland rice producers. The right IPM strategy may be different from case to case and can consist of different components chosen from the ones proposed in the above table.

8.2 Recommended rice varieties

The most important criterion for rice varieties to be planted in the CARI program is high yield (up to 6.000 kg/ha for irrigated rice). Varieties that grow strong and not too high are recommended, in particular if they have some tolerance as far as biotic and abiotic stress factors are concerned. AfricaRice has released suitable varieties that are listed in tables 17 and 18 on the following page.

Rice varieties with tolerance against RMYV include LAC23, Moroberekan, IR 47686-1-1 for direct seeded rainfed lowlands; and WITA 9, WITA 11 and Gigante (tete) for irrigated lowlands. Use of traditional *Oryza glaberrima* varieties such as TOG 5674, 5675, 5681, 7235, 7291, and others has also been recommended.

Stalk-eyed shoot fly (*Diopsis* spp.) management includes cultivation of the tolerant variety WAB 1159-2-12-11-6-9-1-2 with highly hairy leaves can trap *Diopsis* larvae.

African Rice Gall Midge (AfRGM) Management:

For AfRGM-affected areas tolerant rice variety can be used:

- Cisadane (FARO 51), BW348-1, Leizhung
- traditional *Oryza sativa* varieties such as TOS 14519
- tolerant lowland NERICA varieties, e.g. NERICA L-25, NERICA L-19, NERICA L-29, NERICA L-49
- traditional *Oryza glaberrima* varieties such as TOG 7106, 7206, 7442, 6346, 5681, and others

Rice varieties such as LAC 23, NERICA 1, 2, 5, 14 and others have proven to be more tolerant towards termite attack than others.

Table 17: Recommended lowland rice varieties (according to CARI, AfricaRice and the crop variety catalogue published by NACGRAB and N.A.S.C in 2013; varieties printed in bold letters have been recommended by local experts during the consultant's mission)

Variety	Characteristics and comments
FARO 44 (SIPI)	Medium maturing variety; blast resistant; tolerant to iron toxicity; long grain; optimum production under low management conditions
FARO 51 (Cisadane)	Suitable for areas affected by the African gall midge
FARO 52	High yielding; tolerant to iron toxicity and drought; partially tolerant to RYMV; long grain
FARO 57	High yielding; medium maturing variety with long, slender grain; resistant to blast, drought, iron toxicity and RYMV
FARO 60 (Nerica L19)	Late maturing
FARO 61 (Nerica L34)	Late maturing

Table 18: Recommended upland rice varieties (according to AfricaRice)

Varieties	Characteristics and comments
FARO 1, 40, 45, 54, 55 (NERICA 1), 56 (NERICA 2)	Early maturing (< 90 – 100 days)
FARO 48, 49, 53	Medium maturing (100–120 days)
FARO 25	Late maturing (> 120 days)
LAC 23, ITA 121, TOS 4153, NERICA 1, NERICA 2, NERICA 4, NERICA 5, NERICA 7	Stem borer tolerance

8.3 Rice pesticides with good action profiles and comparatively low hazards

Pesticide use is more common and more economic in high yielding lowland cultivation systems than in low yielding rainfed upland rice. This is why recommendations for upland rice IPM rely less on pesticides than on cultural methods. Nonetheless recommendations are given for both systems and it is left to the discretion of farmers and agricultural extension workers to which extent pesticides will be included in a given situation.

The recommendations given in table 19 below take health and environmental hazards related to substances into account. Active ingredients that pose major risks have not been included in the list below even if they have above average effects on the target organisms.

Table 19: Pesticides that are potentially suitable for rice cultivation in Nigeria (active ingredients printed in bold letters appear to be particularly useful)

Active ingredient	Commercial product and manufacturer	Use	Characteristics and comments
Azoxystrobin	Amistar Syngenta	Systemic broad-spectrum fungicide	Toxic for aquatic organisms, rather quick decomposition in plants and in soil
Bromobutide + fentrazamide	Innova Bayer CropScience	Herbicide	To be applied at the time of transplanting, controls sedges effectively (currently not available in Nigeria)
Ethiprole	Curbix Bayer CropScience	Insecticide	Particularly effective against plant hoppers (currently not available in Nigeria)
Ethoxysulfuron	Tillergold Bayer CropScience	Herbicide	Rather low ADI and high toxicity for aquatic organisms; use with special care (currently not available in Nigeria)
Fenoxaprop-p-ethyl	Ricestar Bayer CropScience	Post-emergence herbicide	Provides effective grass control; no soil residual activity (currently not available in Nigeria)
Flubendiamide	Fame Bayer CropScience	Insecticide (phthalic acid diamide)	Foliar insecticide that provides good caterpillar control with a different mode of action than other insecticides (currently not available in Nigeria; interesting for purposes of resistance management!)
Glyphosate	Original product: Roundup by Monsanto, now many others are available, e.g. Touchdown by Syngenta	Pre/post-emergence herbicide	Because of high aquatic toxicity and high persistence take precautions to avoid water pollution
Isotianil	Routine Bayer CropScience	Fungicide/seed treatment	Effective against rice blast and leaf blight (currently not available in Nigeria)
Pretilachlor + pyribenzoxim	Solito Syngenta	Herbicide	Effective against grasses, sedges and broadleaf weeds in wet-sown and transplanted rice

8.4 Suggestions for supporting action

There is a couple of measure that CARI could fund to support introduction of recommended IPM practices. These measures include the ones listed below:

- Making innovative pest control equipment available in all rice growing areas of the CARI program (including rodent and bird nets, triple bags and any other suitable equipment)
- Training professional pest control operators (including in proper use of fumigants under safe conditions)
- Setting up pesticide stewardship programs involving training and promotional sales actions, e.g. pesticide + safety equipment package or sprayer + safety equipment package
- Providing improved safety equipment (e.g. face shields instead of dust masks)
- Selling pesticides, sprayers, protective equipment and other agricultural inputs in the same place to facilitate adoption of good IPM and safety practices
- Support drawing up of pesticide policy taking into account environmental and human health criteria
- Support drafting of a pesticide act

8.5 Disseminating the IPM message to the farmers

Nwilene & al. (2013) comment on the best ways how to instruct farmers on IPM practices. They highlight the farmer field school (FFS) for IPM as an innovative model for community-based farmer education that uses non-formal or 'discovery learning' methods. Participatory learning and action-research (PLAR) for integrated rice management developed by AfricaRice is also a promising approach to reach out to farmers. Its essential feature is a "*... bottom-up social learning process to promote technological change through improving farmers' capacity to exchange knowledge, experiences and practices, to better observe, analyse and take appropriate decisions for action, and to get organized for action*".

Indeed, experience has shown that participatory approaches such as FFS or PLAR (which are basically rather similar to each other) are the key to changing farmers' practices for better yields and sustainable cropping systems. It is essential that farmers have the possibility to choose, try and evaluate themselves and to draw their proper conclusions. Apart from field demonstration and evaluation the Farmer Business School approach (Matthess, 2014) is a valuable training tool to support farmers in taking economically sound decisions. It is recommended to take IPM issues into account more systematically in this approach. Appropriate training material for this purpose is discussed in the next chapter.

8.6 Cost-effectiveness of IPM recommendations

Cost-effectiveness has been a major criterion for all recommendations made in Sections 4.3 and 8.1 of this report. As the information on losses provided in Section 4.1 shows, rice crop losses can be substantial if no IPM control measures are implemented. Out of different effective and environmentally sound options, generally the least expensive ones have been recommended in this study. Two examples may illustrate this point:

- **Benefit of herbicide use instead of hand weeding:**
As Shaibu (2011) pointed out 120 hours of manual weeding can be replaced by 4 hours of herbicide application. Using the cost indicated by Matthess (2014), 120 hours (15 MD) cost

₦ 12000, while cost for herbicide application is ₦ 400 for 0.5 MD + cost of herbicide (₦ 4400), i.e. a total of ₦ 4800 which is less than half the cost of manual weeding (let alone the social and economic benefits of releasing farm household members, in particular women and children from this tedious task).

- **Bird nets instead of chasing and scaring:**

According to information obtained during the visit to the ADP rice fields in Lokoja, covering one hectare of the ripening crop to protect it from quelea birds would cost about ₦ 11000 while chasing and scaring of birds would take about two persons over a period of time of up to 24 days. Nets may be used 1 – 2 years corresponding to 2 to 4 cropping seasons so that the cost for one season is ₦ 3667 on an average which is equivalent to about 4.5 MD which would just cover about 2 days of chasing and scaring which would be hardly ever sufficient. Apart from this the net is permanently in place while people doing the chasing and scaring job may not be in place early enough one of the mornings when the birds arrive so that substantial damage may already occur. Here again, the social and economic dimension of the task must be taken into account, too.

The examples included in the Farmer Business School notebook by Matthes (2014) demonstrate clearly that an increase in income of ₦ 119100 per hectare can be achieved using good agricultural practices including IPM (pages 23 and 30 of the notebook). Certainly it is difficult to assess which part of the increase in yield and income can be attributed to IPM measures alone but it is obvious that in the traditional system with an input for pest control of ₦ 18200 (for manual weeding and chasing birds), a profit of only ₦ 48800 can be made while with investing ₦ 29900 (i.e. just ₦ 11700 more) and using additional best practices a profit of ₦ 167900 is possible. As insufficient weed control alone can lead to substantial crop losses (up to 100 %) this investment appears to be by all means justified.

9 Assessment of suitability of existing training and advisory materials for smallholder training in IPM

9.1 Africa Rice Center brochures

The Africa Rice Center (called WARDA before, now AfricaRice) published brochures that deal with smallholder lowland and upland rice production in Africa including pest management (Nwilene & al. (no year) and Oikeh & al. (no year)). These brochures are focused on the region where the CARI program is operating and therefore particularly helpful. They are well written and illustrated and organised in a straightforward and systematic way. However, they require considerable command of agronomic knowledge and English language and are particularly useful for agricultural extension workers with special knowledge. In addition, some recommendations require amendments in the light of social aspects (e.g. hand weeding that may be a heavy burden on women and children) or technical issues (e.g. fumigation of stored rice which cannot be done without proper sealing by untrained farmers because of extreme toxic hazards). Some of the pesticide recommendations are outdated and should not be followed any longer (see Chapter 3 for details).

A rather detailed account on rice production using improved varieties (NERICA) is given in the compendium of Somado & al. (2008). This publication is a rich source of information for qualified rice R&D workers. Apart from this there is more specialized material available such as a field guide on biology, ecology and control of the African Rice Gall Midge published by Nwilene & al. (2006). Carefully countercheck pesticide recommendations in this publication because carbofuran is outdated by now (see Chapter 3).

9.2 IRRI brochures

The widespread IRRI brochure „Field Problems of Tropical Rice“ first published in 1983 and translated in different languages provides illustrations and short descriptions of tropical rice pests, diseases, weeds and abiotic constraints and can be of considerable help to people familiar with rice damage and losses caused by biotic and abiotic factors. However it consists just of very short profiles of loss agents without providing any context and hardly any IPM recommendations. Not all pictures depict the pests or the symptoms particularly clearly. The brochure can provide a quick overview but the brochure would not be of much help for most of the smallholder farmers in the CARI target countries. The same applies to the “Friends of the Rice Farmer” brochure written by Shepard & al. in 1987 which presents beneficial insects, spiders and pathogens.

IRRI published other training and advisory material available from their website that is either of a more general nature or focused on rice production conditions in Southeast Asia which can serve as a valuable source of information but which cannot be used directly for the special requirements of rice farmers in African countries.

9.3 CARI Producer’s Reference Nigeria

This brochure published by GIZ (2014) is written and illustrated in an appealing style introducing rice production problems and solutions through a smart female farmer. The language is simple enough to be easily understood. This producer’s reference covers the complete range of good agricultural practices and economic aspects of rice production including IPM issues. It supports training provided in a series of 8 extension sessions. The consultant assigned for this study took the opportunity to include appropriate recommendations on sound and sustainable rice IPM methods. Translation into local languages and broad distribution is recommended.

9.4 CropLife International guidelines

CropLife International has published guidelines for risk mitigation connected to pesticides. These guidelines are intended for use by agricultural extension workers and farmers as well. For the CARI programme those dealing with personal protection and emergency measures in case of pesticide intoxication are the most relevant ones:

- Guidelines for Personal Protection When Using Crop Protection Products in Hot Climates (2005)
- Guidelines for emergency measures in case of crop protection product poisoning (1997)

These guidelines describe proper use of pesticides and emergency measures in a clear and simple way and use illustrations that depict essential issues precisely.

9.5 Other material

ProAgri (no year) produced a picture block on integrated cotton pest management. The format of this extension tool appears very much appropriate to train farmers on the topic. A similar picture block should be produced for rice IPM in Nigeria as proposed by the CARI program leader, S Kachelriess-Matthess, taking into account the peculiarities of the rice agro-ecosystem (cf. table 15 in this study). There is another ProAgri picture block on good practices in pesticide use focused in

cotton production. This block can easily be adapted to the situation in rice production i.e. modifying some illustrations (e.g. picture on the title, scenes 6 – 8, 10 – 12 and 16) and improving some details that are not entirely up to date (e.g. hazards symbols to be exchanges with GHS symbols – scene 5, type of protective mask worn – scene 6 and throughout other illustrations). Such picture blocks are very much appropriate for use by extension agents during training sessions.

Youdeowei (2002) published a series of Integrated Pest Management Extension Guides. One of it (guide 2) deals with cereals and pulses including rice. Guide 2 summarizes main rice pests and diseases and includes a beautiful colour illustration precisely depicting symptoms and their causing agents drawn by the Ghanaian artist E Opare. This series of guides has been developed in the course of an integrated crop protection project implemented by GIZ (called GTZ at that time). The guides describe step by step appropriate procedures and actions and are clearly structured and easily understandable. The IPM principles underlying the brochures are based on the agro-ecosystem analysis (AESA) decision-making tool developed by FAO. AESA is a participatory recommended approach for IPM decisions but it does not include economic threshold limits.

The TG-PPP Rice Pest Surveillance Manual published in 1988 refers to another rice production environment (Thailand) with a different pest ecosystem and is outdated in some aspects (e.g. insecticide recommendations) but its methodological approach is excellent and can serve as a basis for new training material for agricultural extension workers. Its main relevant contents should be summarized and updated and made widely accessible in the CARI programme context.

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Annexes

Annex 1: Terms of Reference of the consultant's mission

Annex 2: Course of the mission

Annex 3: Documentation of stakeholder forums on IPM

Annex 4: Photos taken during the mission